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ON THE DOUBLE CARBIDE OF HIGH SPEED STEEL

By Arne Westgren and Gosta Phragmen

Abstract

By means of X-ray analysis the authors have proved the identity of the high speed steel carbide with octahedral crystals grown in blowholes of ferrotungsten. Laue and rotation photograms have shown that the crystal lattice of this phase is face-centered cubic; its elementary cube is probably occupied by 112 atoms. Several Fe-W-C melts have been synthesized in order to produce this phase, which is an iron-tungsten carbide, in a homogeneous state but all attempts in this direction have failed, as melts of a composition approaching that of the high speed steel carbide have turned out to be peritectic. A microscopic investigation of these alloys as well as the X-ray crystallographic data and figures obtained through chemical analysis by previous investigators all show that the composition of the high speed steel carbide corresponds to the formula Fe_4W_2C. X-ray photograms of Fe-Mo-C alloys have proved the existence of an iron-molybdenum carbide analogous to that of the iron-tungsten carbide of high speed steel.

ON examining an annealed high speed steel under the microscope the observer is struck by the fact that it contains a much greater quantity of carbide than a plain carbon steel of corresponding carbon content. Already from this fact it is evident that the carbide in question cannot be cementite. Many attempts have been made to determine its true nature but so far with no definite success.

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. Of the authors, Arne Westgren is professor of general and inorganic chemistry at the University of Stockholm and Gösta Phragmén is associated with the Metallografiska Institutet, Stockholm, Sweden. Manuscript received August 5, 1927.

$(Fe,W)_6C$

By the old method of dissolving the iron phase of steel in dilute hydrochloric acid and analyzing the remaining carbide powder, Arnold, in collaboration with Read[1] and with Ibbotson[2] has tried to solve the problem. From the figures obtained they concluded that the carbide of high speed steel is a mixture of Fe_2W, WC, Cr_4C and in some cases also of Fe_3C and V_4C_3. A magnetometric analysis of high speed steel, performed by Honda and Murakami[3] led up to a confirmation of this conclusion. This very complicated result of Arnold and Read[4] concerning the steels high in tungsten, is somewhat surprising in view of the fact that the same authors found the carbide of molybdenum steels, sufficiently high in molybdenum, to consist only of the double carbide Fe_3Mo_3C. As will be seen in the following, the carbide constituent of high speed steel consists in fact entirely, or at least not far from completely, of an iron-tungsten carbide, analogous to the iron-molybdenum carbide of the molybdenum steels.

Grossmann and Bain[5] have also analyzed carbide powder which was isolated by electrolytic dissolution of high speed steel in dilute hydrochloric acid. The analytical data obtained by them, on the whole, agree with those given by Arnold and Ibbotson, i. e. the carbon content was found to be only 2.3 per cent and the tungsten percentage somewhat above 60. From their analytical results Grossmann and Bain inferred that in an annealed high speed steel the entire content of tungsten and vanadium, but only about half of the chromium, is combined with the carbon as carbide, and that the carbide constitutes about 20 per cent by weight of the steel, i. e., about three times as much as the cementite in a carbon steel of corresponding carbon content.

Six years ago one of us obtained an X-ray photogram of an annealed high speed steel, which showed that this steel contains a phase which is neither an iron modification nor cementite[6]. It

[1]Arnold, J. O., and Read, A. A., *Proceedings*, Institute Mechanical Engineers (London), No. 2, p. 223, 1914.

[2]Arnold, J. O., and Ibbotson, F., *Journal*, Iron and Steel Institute, 99, p. 407, 1919.

[3]Honda, K., and Murakami, T., *Science Reports*, Tohoku Imperial University, 9, p. 143, 1920: *Journal*, Iron and Steel Institute, 101, p 647, 1920.

[4]Arnold, J. O., and Read, A. A., *Proceedings*, Institute Mechanical Engineers (London), No. 2, p. 629, 1915.

[5]Grossmann, M. A., and Bain, E. C., *Journal*, Iron and Steel Institute, 110, p. 249, 1924.

[6]Westgren, A., *Jernkontorets Annaler* 1921, 427; *Journal*, Iron and Steel Institute, 103, p. 322, 1921.

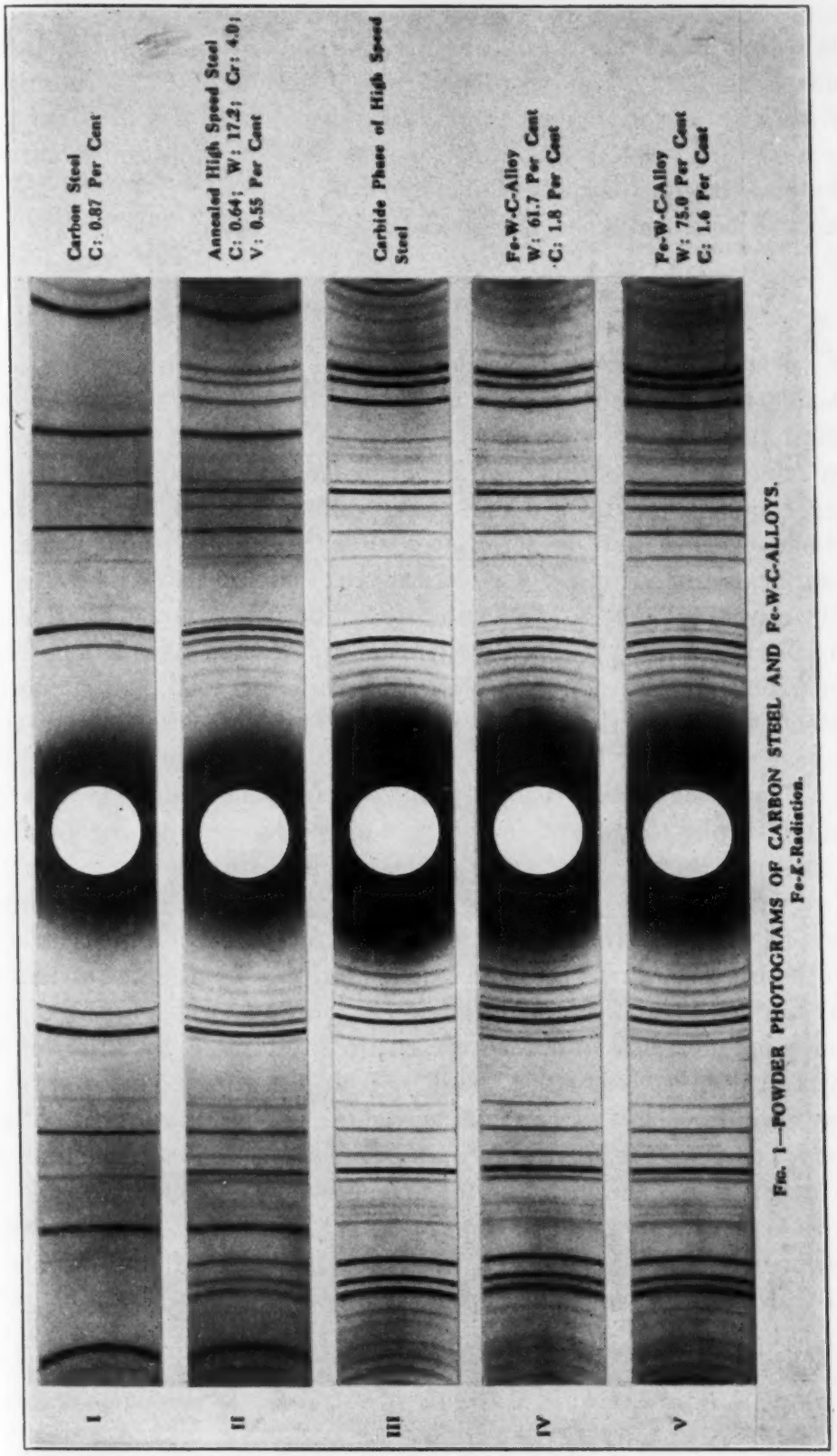

FIG. 1—POWDER PHOTOGRAMS OF CARBON STEEL AND Fe-W-C-ALLOYS.
Fe-K-Radiation.

appeared as though this steel contained a characteristic carbide of its own. The same result was arrived at by Bain and Jeffries[7] by means of X-ray photographs. In connection with a preliminary investigation concerning the iron-tungsten-carbon system we have recently penetrated somewhat deeper into the question regarding the constitution of the carbide in high speed steel. In the following will be given a short description of the results obtained.

X-ray Analysis of the Carbide in High Speed Steel

Fig. 1, I, is a powder photogram of an annealed carbon steel. Beside the interferences of alpha iron, there are some faint lines, originating from the cementite. Fig. 1, II, is an X-ray pattern of an annealed high speed steel (carbon 0.64 per cent; tungsten 17.2 per cent; chromium 4.0 per cent; vanadium 0.55 per cent). A whole series of new interferences appear here, some of which are comparatively strong. An electrolytic dissolution of the steel in dilute hydrochloric acid gave as a residue a fine powder, of which the X-ray pattern in Fig. 1, III, was obtained. As will be seen, the iron lines have here completely vanished, whereas the other interferences in the X-ray photogram of the high speed steel appear with great intensity.

The same line series as that seen in photogram III was obtained in photograms of ferrotungsten specimens with carbon from 2 to 3 per cent. But on the other hand it did not appear in the X-ray patterns of carbon-free iron-tungsten alloys. Consequently, the phase which gives this series of interferences must be a carbide. As the line series neither corresponds with the photogram of cementite nor with the X-ray pattern of any carbon-tungsten phase[8], the phase in question cannot be cementite substituted by tungsten or any tungsten carbide substituted by iron but must be an iron-tungsten carbide. Thus, it is a double carbide in the proper sense of the word, i.e. a carbide for the formation of which besides carbon atoms at least two other kinds of atoms are necessary.

On the surface and in the cavities of some of the iron-tungsten specimens investigated, octahedral crystals were found of about 0.5 millimeter size. Their powder photogram corresponds with

[7]Bain, E. C., and Jeffries, Z., *Iron Age*, 112, p. 205, 1923.

[8]Westgren, A., and Phragmén, G., *Zeitschrift für Anorganische und Allgemeine Chemie*, 156, p. 27, 1926.

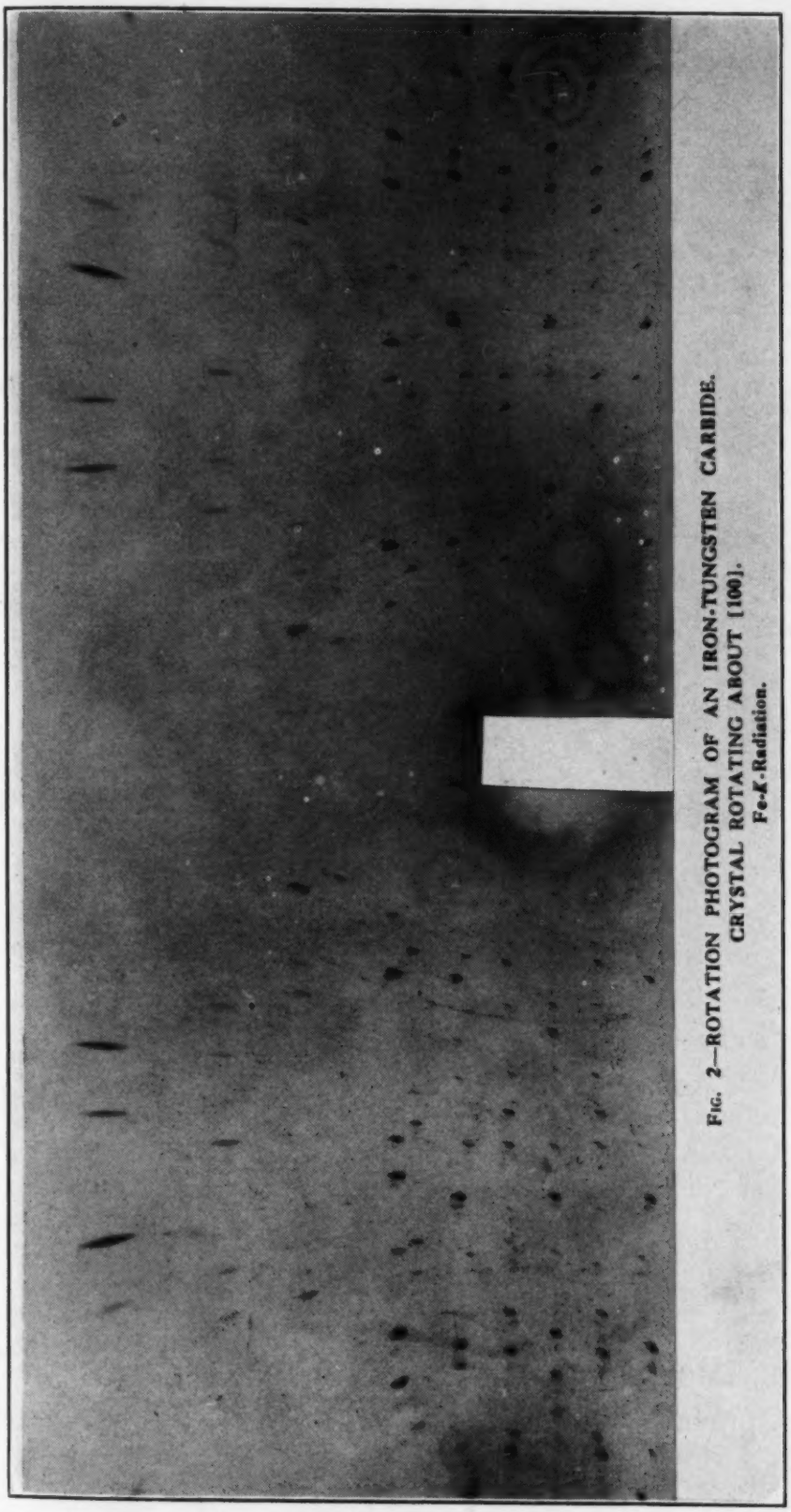

FIG. 2—ROTATION PHOTOGRAM OF AN IRON-TUNGSTEN CARBIDE.
CRYSTAL ROTATING ABOUT [100].
Fe-K-Radiation.

Table II

Powder Photogram of High Speed Steel Carbide

I	Radiation	Σh^2	$\sin^2 \frac{\theta}{2}$	$\frac{\sin^2 \frac{\theta}{2}}{\Sigma h^2}$
v. w.	α	11	0.0845	7.68
w.	β	16	0.101	6.31
w.	β	19	0.120	6.32
m.	α	16	0.123	7.68
st.	α	19	0.1455	7.66
m.	β	24	0.1515	6.31
m.	β	27	0.170	6.30
st.	α	24	0.184	7.67
w.	β	32	0.202	6.31
st.	α	27	0.207	7.67
v. w.	α	..	0.2255	...
st.	α	32	0.246	7.69
w.	α	36	0.277	7.69
v. w.	α	40	0.308	7.70
w.	β	51	0.322	6.31
v. w.	α	44	0.338	7.68
w.	β	59	0.373	6.32
st.	α	51	0.3905	7.66
w.	β	67	0.4225	6.30
st.	α	59	0.4535	7.68
v. w.	β	75	0.4735	6.31
v. w.	α	64	0.491	7.67
st.	α	67	0.514	7.67
st.	α	72	0.551	7.65
st.	α	72	0.5535	7.68
m.	α	75	0.574	7.66
m.	α	75	0.5765	7.69
w.	β	99	0.624	6.30
w.	α	83	0.636	7.66
w.	α	83	0.6385	7.69
w.	α	84	0.6425	7.65
v. w.	α	84	0.6455	7.68
w.	β	104	0.6555	6.30
m.	α	88	0.674	7.66
w.	α	88	0.677	7.69
st.	α	99	0.757	7.65
st.	α	99	0.7605	7.68
st.	α	104	0.796	7.65
st.	α	104	0.799	7.68
st.	α	107	0.8185	7.65
st.	α	107	0.822	7.68
w.	α	108	0.826	7.65
w.	α	108	0.830	7.68
w.	β	136	0.8575	6.31
w.	β	139	0.876	6.30
v. w.	α	115	0.880	7.65
m.	β	114	0.9075	6.30
w.	α	120	0.918	7.65
v. w.	α	120	0.922	7.68
st.	β	147	0.926	6.30
m.	α	123	0.941	7.65
m.	α	123	0.945	7.68
st.	β	152	0.9575	6.30

been investigated by Behrens and van Linge[9]. They found that the composition of the crystals corresponded to the formula Fe_2W. They discovered also that the crystal powder contained a slight

[9]Behrens, H., and van Linge, A. R., Recueil d. trav. chim. des Pays-Bas, 13, p. 155, 1894.

quantity of carbon but this was considered to be an impurity. It is mainly on their statements that the view is based that there exists a tungstide Fe_2W, which until quite recently has played an important rôle in many explanations of the structure of tungsten steels and ferrotungsten alloys[10]. In reality, there is scarcely any doubt that it was no iron-tungsten phase but the double carbide of high speed steel which the two Dutch investigators examined.

An analysis of some crystals of this type, kindly collected and put at our disposal by E. Fornander, Sandviken, gave the following figures: W = 69.4 per cent, Fe = 28.0 per cent, C = 1.1 per cent. Considering that these crystals had crystallized in a ferrotungsten containing about 85 per cent W and 0.5 to 1.0 per cent C, and that they in all probability were not perfectly free from the melt in which they had crystallized, these values indicate that iron and tungsten are combined in the high speed steel carbide in proportions approximately corresponding to the formula Fe_2W, (W: 62.2 per cent). This conclusion is also supported by the analytical data mentioned above for the high speed steel carbide, obtained by Grossmann and Bain as well as by Arnold and Ibbotson.

The prospect of obtaining a homogeneous melt of the high speed steel carbide therefore seemed most promising if an alloy of a composition approximately corresponding to Fe_2W was melted together with a suitable quantity of carbon. Electrolytic iron and tungsten were therefore mixed in the said proportions, and were melted with varying quantities of graphite, in a vacuum furnace, using magnesia crucibles.

As evidenced by photograms IV and V in Fig. 1, the alloys, containing about 2 per cent carbon, were found to consist principally of high speed steel carbide. The alloys were examined microscopically and some photomicrographs of those containing most high speed steel carbide, are shown in Fig. 4. The composition of these alloys, determined by chemical analysis of Fe, W and C, is given in the caption of the photomicrographs.

A distinct differentiation of the different structural constituents present in these specimens was obtained by tempering them to a blue or red color. An alloy containing 62 per cent W and 1.8 per cent C (Fig. 4, I) shows the high speed steel carbide forming dendrite skeletons of almost one centimeter in size, the interspacing

[10] According to W. P. Sykes, *Transactions*, American Institute of Mining and Metallurgical Engineers, 73, p. 968, 1926, the formula of the intermediate phase appearing in the Fe-W system should be Fe_3W_2 and not Fe_2W.

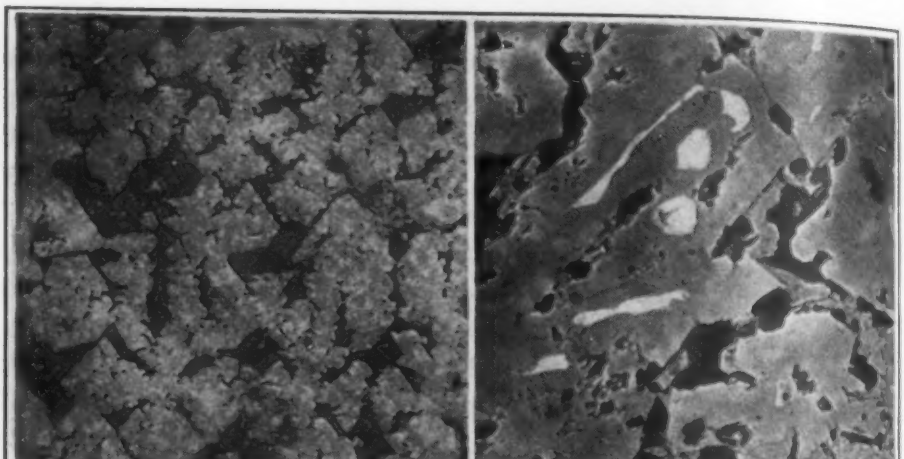

Fig. 4—PHOTOMICROGRAPHS OF IRON-TUNGSTEN-CARBON ALLOYS. Magnification 200 x.

being filled by a fine-grained ternary eutectic of this carbide and two other phases. An inspection of the photograms taken in the focusing cameras showed that besides the lines corresponding to the high speed steel carbide also some faint interferences appear belonging to alpha iron (to be seen also in Fig. 1, IV) as well as from another Fe-W-C-phase besides the one of high speed steel. We have been able to obtain crystals of this last mentioned phase, crystallized in a ferrotungsten with about 85 per cent W and 0.5

per cent C.[11] Laue and rotation photograms of one of these crystals showed that it had a trigonal, very complicated structure. As its photogram corresponds neither with any Fe-W, W-C, nor with any Fe-C-phase, it too must be a double carbide of iron and tungsten. It appears more abundantly in melts of a lower carbon content, and is thus poorer in carbon than the high speed steel carbide. As it further appears primarily crystallized in ferrotungstens of a high tungsten content, it seems probable that it is richer in tungsten than the high speed steel carbide.[12]

As the alloy in question has thus been found to consist of high speed steel carbide mixed with a slight quantity of iron and a double carbide poor in carbon, it seemed close at hand to assume that a slight increase in the carbon content would be sufficient to render a practically homogeneous melt of high speed steel carbide. However, as is to be seen from Fig. 4, II, an alloy with 62 per cent W and 2.0 per cent C contains no less than four phases. The high speed steel carbide grains are very large in this alloy but in the center of some of them are to be found small, white crystal grains, with an aspect as if they had been attacked by the melt after the solidification. Between the big angular crystals of high speed steel carbide appear some lighter, irregularly shaped grains of the trigonal double carbide, poorer in carbon, and between these, as the last solidified product, a ternary eutectic of the two double carbides and iron. The system seems to be peritectic on the carbide side. We have not yet been able to determine the composition or the crystallographic characteristics of the primarily solidified phase. We have only found that it appears more abundantly if the carbon percentage is still further increased. Further, from the faint lines, appearing in the photograms, belonging to this phase we think we may be justified in concluding that we have here to deal with a third iron-tungsten carbide.

Fig. 3, II shows a photogram of the last mentioned alloy. The lines are somewhat diffuse, owing to an uneven distribution of the tungsten content within the crystals of the high speed steel carbide, caused by segregation. A comparison with the photogram of the carbide powder isolated from the annealed high speed steel, (Fig. 3, I), however shows that the lines of the synthetic alloy are

[11]For these crystals we are indebted to Mr. E. Berg, Wikmanshyttan, whom we herewith beg to accept our cordial thanks.

[12]Concerning this phase see further authors' reply to written discussion, page 553.

displaced in the direction of smaller diffraction angles. The parameter of the lattice of the cubic carbide in the alloy is 11.08 Å, while the carbide of the high speed steel has a parameter of 11.04 Å.

As the tungsten atoms are considerably bigger than the iron atoms, this difference in lattice dimensions implies that the carbide of the synthetic alloy is richer in tungsten than that of the high speed steel. Iron and tungsten atoms can evidently to a certain extent replace each other in this double carbide. Thus, if the carbide phase of high speed steel possibly might be considered to be an iron-tungsten carbide, in which some of the tungsten is substituted by iron, it seemed possible that melts of a somewhat higher tungsten content with a suitable carbon percentage, would render a homogeneous high speed steel carbide. Iron was therefore alloyed to tungsten, in proportions amounting to 65, 70 and 75 per cent W, with different quantities of carbon. These alloys, however, at a rising percentage of carbon, also gave the same structure series as the above mentioned melts. In these alloys, richer in tungsten, the primarily crystallized white phase of the peritectic alloys, as seen in Fig. 4, III and IV, even seemed to be present in greater quantities than in the alloys first produced.

Although the attempts to make a melt, consisting only of high speed steel carbide thus have proved unsuccessful, it is evident from the alloys investigated that the carbon content of the high speed steel carbide must be about 2.0 per cent. The alloy containing 62 per cent W and 1.8 per cent C is poorer in carbon than the high speed steel carbide, and if the carbon content exceeds 2 per cent new phases appear, in all probability richer in carbon. When the carbon reaches 2.5 per cent the characteristic trigonal, very hard crystals of WC appear abundantly.[13]

The high speed steel carbide seems thus to have a composition corresponding to Fe_4W_2C, (61 per cent C), i.e. with one metal atom to six carbon atoms. As evidenced by the displacement of the interference lines at an increased tungsten content of the alloy (Fig. 3) it is however clear, as indicated above, that to a certain extent iron and tungsten atoms can replace each other in this phase. Fe_4W_2C, which corresponds to the composition of the carbide when in equilibrium with the iron phase, thus should represent only one of the limits of the homogeneity range. So far, we have not been able to determine the position of the other limit.

[13]See foot note 8.

Possibly, it is not far from Fe_3W_3C. This supposition is supported by the following facts. As mentioned above Arnold and Read[14] isolated a carbide powder from a molybdenum steel of a high molybdenum content, and found that its composition corresponded to the formula Fe_3Mo_3C. X-ray photograms of Fe-Mo-C-alloys, obtained by us, show that the iron-tungsten carbide of high speed steel has its analogy in an iron-molybdenum carbide of the same crystal structure.

If we look upon the alloy richest in high speed steel carbide, viz., the one containing 61.9 per cent W and 2.0 per cent C as an approximately homogeneous high speed steel carbide, we might from its density (12.0) and average atomic weight, (86.9) calculate the number of atoms per elementary cube, arriving at the number of 114. (The absolute weight of an atom with an atomic weight of 1 being 1.65×10^{-24} grams). As the lattice is face-centered the number of atoms, in the elementary cube must be a multiple of 4. The numbers of this kind, approaching nearest to 114, are 116 and 112. As the constitutional atom group is one fourth of this, it would consequently comprise either 29 or 28 atoms. The former number is improbable, as it would mean that the formula of the high speed steel carbide should embrace 29 atoms. The latter number on the contrary is well compatible with the supposed formula Fe_4W_2C, as it must be considered to be quite plausible that the elementary cube contains 16 such groups.

This investigation has thus not led to any definite determination of the formula of the high speed steel carbide. It may however be considered certain that all the carbon, or at least by far the greater part of it, (vanadium may possibly form special carbides) is present as an iron-tungsten carbide, the composition of which closely corresponds to the formula Fe_4W_2C.

In this phase some of the chromium probably enters as a substituent for iron or tungsten, or for both of these metals. It is interesting to note that tungsten and carbon are combined in this double carbide in about the same mutual proportions as in the high speed steel, which generally holds about 0.6 per cent C and 17 to 18 per cent W.

This report is only of a preliminary nature, and we hope in the future, through continued investigations on the Fe-W-C, and

[14] See foot note 4.

the Fe-Mo-C systems, to be able to contribute further to the question of the carbides present in tungsten and molybdenum steels.

Summary

An X-ray crystallographic investigation of the carbide constituent of high speed steel has shown that this entirely, or at least mostly, consists of an iron-tungsten carbide, which is neither an iron substituted tungsten carbide nor a tungsten substituted cementite but a double carbide in the proper sense of the word. It has a face-centered cubic crystal lattice, and probably there are 112 atoms in the elementary cube. The edge of the elementary cube is 11.04 Å.

Attempts to make synthetically an alloy, consisting entirely of this high speed steel carbide, have failed but almost homogeneous melts have, however, been produced. The microscopic investigation of these, the X-ray crystallographic data as well as information gained through chemical analysis by Arnold and Ibbotson, Grossmann and Bain, and others, have shown that its composition corresponds to the formula Fe_4W_2C. In this phase iron and tungsten atoms can replace each other to some extent. Thus, the formula Fe_4W_2C only denotes the limit of the homogeneity range on the iron side.

An analogous iron-molybdenum carbide corresponds to this iron-tungsten carbide.

We are much indebted to the Swedish Ironmasters' Association (Jernkontorst) for having financially supported our work, and we also beg to thank Gimo-Osterby Bruks A. B., Dannemora, who has kindly put material at our disposal.

DISCUSSION

Written Discussion: By Zay Jeffries, Cleveland.

Those interested in steel are indebted to the authors for another important contribution. In *Iron Age*, September 27, 1923, there was published an article by E. C. Bain and the writer, entitled, "Cause of Red Hardness of High Speed Steel," in which it was stated that only one intermetallic compound, as evidenced by X-ray crystal patterns, existed in annealed high speed steel. We did not work out the specific structure of this compound but it is interesting to note that the pattern was the same as the one that the present authors obtained. It is an important addition to our knowledge to have the specific structure of this compound and to confirm the observations of Mr. Bain and the writer, that only one inter-

metallic compound seems to be present in annealed high speed steel. Our work led us to the conclusion that other compounds, particularly, Fe_3C, might form at room temperature and at temperatures up to say 450 to 500 degrees Cent. after quenching, but that the double carbide containing both iron and tungsten was so stable that when the tungsten atoms could diffuse, it formed to the exclusion of or even with the elimination of any other intermetallic compound. It would be interesting to have the authors' views on this point.

It is a further important addition to our knowledge to have the formula of the double carbide in high speed steel so definitely determined. Bain and the writer assumed that chromium and vanadium might replace either tungsten or iron to a certain extent without changing the type of crystal lattice. The present authors' experimental results showing the same type of crystal structure with and without chromium and vanadium strongly suggests this possibility.

Since Mr. Bain and the writer offered the views regarding the cause of red hardness of high speed steel, Mr. Sykes has shown that the precipitation of Fe_2W_2 from a supersaturated solution of tungsten in iron takes place only very slowly at about the temperature which was suggested as the lowest temperature at which tungsten atoms could diffuse in iron. Mr. Sykes obtained critical dispersion of Fe_2W_2 which was accompanied, not only with great hardness at room temperature, but also at red heat. This work of Mr. Sykes is evidence that a fine precipitate of hard particles can produce red hardness. It is also in line with the suggestion that a fine precipitate of the double carbide forms at a dull red heat in quenched high speed steel. The new results of Westgren and Phragmen reported in the present paper, offer still further evidence that the above conception is substantially correct. The essential difference between Sykes' carbon-free material and high speed steel in the red hard condition is that in the carbon-free material of Sykes, the alpha iron grains are large and in high speed steel the alpha iron grains are small. It would be interesting to have the authors' views on this subject.

Authors' Reply to Written Discussion

We are indebted to Dr. Zay Jeffries for his having raised a point in the discussion that was not perhaps sufficiently clearly elucidated in our paper.

The carbide powder isolated from a high speed steel only giving interferences corresponding to the cubic double carbide, may not be considered to be a proof that this substance is the only carbide phase present in the steel. Other carbides may eventually occur. If their symmetry is low or if they are present in small quantities, their lines cannot be expected to show up in the photograms. Thus, our photograms do not disprove the possibility of cementite being present in the carbide powder of annealed steels to a slight amount of say 10 per cent or less. The hypothesis of Mr. Bain and Dr. Jeffries that other compounds, particularly Fe_3C, might form at the tempering of quenched high speed steel may perhaps be tested by dividing the carbide suspension obtained by partial dissolution of the steel into fractions of different sedi-

mentation velocity. Eventual cementite grains might then be concentrated in the lighter fractions and identified by X-ray analysis.

We are in accord with Bain and Jeffries that one of the main causes of red hardness of high speed steel possibly is to be sought in the maintaining of a fine precipitate of double carbide in the steel.

We are glad in this reply to the discussion to be able to give further information concerning one point in our paper. We stated that the Fe-W-C melt of lower carbon content beside the cubic carbide and iron also contained a third phase, which we believed was another iron-tungsten carbide. If this phase is identical with the trigonal crystals we had found in ferrotungsten of high tungsten and low carbon content, it is, however, an iron-tungsten phase, as recently proved by H. Arnfelt at Metallografiska Institutet of Stockholm.

Mr. Arnfelt has found that the Fe-W system contains at least two intermediate phases. One is hexagonal, containing 12 atoms in its unit cell. A chemical analysis of this phase, isolated in a pure state, has proved its formula to be Fe_2W. This seems to be the only intermediate Fe-W phase, stable at ordinary temperature. Another iron tungstide is found in the form of thin crystal plates in Fe-W melts holding about 50 per cent W. It is identical with the trigonal crystals, mentioned above, found by us in ferrotungsten. It has a highly complicated structure. Mr. Arnfelt is now trying to determine its elementary dimensions and to determine, under which conditions it is stable.

ON THE THEORY OF HEAT

By Henry Le Chatelier

Abstract

In this discussion of the theory of heat, the author covers the problems of suitable heating—the supplying simultaneously of the required amount of heat and the temperature necessary for carrying out the contemplated action. Also the cost of heating—fuel, labor and maintenance, which is exactly proportional to the consumption of calorific energy.

He points out that there are many factors which play an important part in heat theory, for instance, the transfer of heat and its utilization are controllable by the laws of energetics, also the effect of passive resistance and conditions of reversibility. The different types of perfected apparatus are explained, particularly the shaft furnace, with its current gases, and the burning of quartz is followed through. The importance of an even distribution of temperature within the furnace and its necessary limitation as applied to the melting cupola.

LET us first state the problem of heating: Suitable heating of a certain material is to be obtained at a minimum cost, using a given source of heat. Examples: Vaporization of water in a boiler, melting of metal, burning of lime etc. In every case the heating process is to supply, simultaneously, the required quantity of heat and the temperature necessary for carrying out the contemplated reaction. For instance, in the manufacture of lime, the burning of 1 kilogram of calcium carbonate, say 10 moles, will require at least 400 calories available at a temperature of 1650 degrees Fahr. (900 degrees Cent.) or more.

The most important elements of the cost of heating are primarily those pertaining to the direct cost of generating heat. They are the cost of fuel, or any other analogous source of heat, then the cost of labor, amortization, and maintenance of the heating equipment. These expenses are sensibly proportional to the cost of generated heat. With regard to the general cost we may,

A paper presented by title before the eighth annual convention of the society, Chicago, September, 1926. The author, Henry Le Chatelier of Paris, France, is an honorary member of the society.

therefore, safely admit that the cost of a heating operation is exactly proportional to the consumption of calorific energy. The better the latter is utilized, the lower will be the cost of heating.

Consequently, the problem of heating is essentially a problem of efficiency. When consuming a certain quantity of heat obtained from sources which nature has placed at our disposal, the problem consists in using it to the best advantage, in heating with it the largest possible quantity of material which we desire to so treat. A simple example will illustrate that the efficiency may vary within very wide limits, depending on the method of operation employed.

Suppose that we desire to sterilize a liquid of a constitution similar to that of water, briefly called an aquaeous liquid, by heating it up to 70 degrees Cent., or more, while having at our disposal 1 kilogram of water at 100 degrees Cent. as the entire source of heat. Let us first consider mixing the hot water with the cold liquid, or, what amounts to the same, permit the equalization of temperature through interchange of heat to take place across a heat-conducting wall which separates the two liquids at rest. This would enable us to heat 500 grams of the aquaeous liquid from the room temperature of 10 up to 70 degrees Cent. If we apply, however, a methodical heat interchanger, allowing the liquid which is to be sterilized to enter it at the bottom of the tubes, and the hot water to enter the apparatus at the top between the tubes, then this water will be cold when leaving at the bottom, while an equal weight of the liquid which is to be sterilized, say 1 kilogram, will be at 100 degrees Cent. when it leaves at the top. The latter method of heating will, therefore, have been far more advantageous. By passing through the tubes 1.5 kilograms of the liquid which is to be sterilized for each kilogram of hot water, the former will attain the desired temperature of 70 degrees Cent. When using the temperature interchanger, the efficiency will, therefore, be three times higher. This example sufficiently explains the interest presented by the study of the different methods of utilizing heat.

The Laws of Energetics

The transfer of heat and its utilization are controlled by the laws of energetics. The deliberations of Sadi Carnot on the me-

chanical power of heat are equally applicable to its caloric power. Lord Kelvin has pointed out that the operation of heating according to a perfectly reversible process will render a maximum calorific efficiency. For the heating of residences he proposed that the ordinary stove, which gives an amount of heat at most equal to that generated by the combustion of the coal, be replaced by a machine describing a Carnot cycle, and which raises the temperature of the air taken from the outside by about 15 degrees. We would thus obtain 18 times the amount of available heat liberated by the used fuel. In actual performance we would hardly obtain more than twice the amount of heat furnished by coal, on account of passive resistances which considerably reduce the efficiency of thermal machines. Furthermore this would necessitate the use of very expensive machines and still more burdensome labor, so that it is more economical to burn an excess of coal and to keep the ordinary stoves.

Starting from the same principles, however, Sir William Siemens brought into actual being a system of heating, the so-called recuperation, which has revolutionized all industries using high temperatures. At present the steel and glass industries employ exclusively Siemens' recuperative stoves. At the beginning of his career this scientist worked on the improvement of hot air engines whose efficiency could notably exceed that of the steam engines, conforming to Sadi Carnot's theory. In the latter engines, the rapid increase of the steam pressure prevents the heating of the boiler to a very high temperature. When using gases, on the contrary, this is easy.

The efficiency of the engines, however, depends not only on the difference in temperature of the two sources, but also on to how perfect a degree the operations are reversible. This reversibility is the more perfect the nearer the temperature levels of the bodies between which the temperature interchange takes place. Upon this principle is based the sheet metal recuperator proposed by Ericson and used by Siemens. Unfortunately, it is not possible to use this method beyond the point of oxidation of ordinary iron or copper sheet metal. This difficulty put an end to Siemens' endeavor.

He then conceived the idea that the use of recuperators in connection with heating apparatus would improve the calorific

efficiency in the same way as they improved the efficiency of engines. Unfortunately, Siemens' publications dealing with the description of his stoves show a lack of thorough theoretical discussion. It is difficult to determine whether he was guided by simple considerations of analogy, or whether he delved deeper into the theory of the phenomenon. At any rate, for practical purposes he scored a remarkable success.

I wish, at this point, to elaborate on the exact general theory of heat and to show to what extent the interchange of heat is governed by the laws of energetics. In order to accomplish this, it is necessary to begin by defining the conditions of reversibility and to study them separately from the passive resistances. Although, in practice, we cannot eliminate the passive resistances, it is still highly interesting to study real phenomena mentally stripped of adherent passive resistances and to separate the latter from the active forces. The application of Descartes' principle of division: "Divide every difficulty into as many parts as possible....." is always profitable.

Passive Resistances

In each form of energy the passive resistances assume a special attitude and require a particular examination. They present analogies, of course, but also show important differences. Sadi Carnot compared the utilization of heat dropping from a high temperature to a lower temperature to the fall of a body of water dropping from a high level to a lower level. In the case of water the passive resistances attach to the viscosity of fluids, their friction against the walls of containers, and to the loss of kinetic forces due to abrupt changes in velocity. In the case of heat, the thermal conductivity, or to be more exact, its reverse, i. e. the resistance to the passage of heat, plays a part quite analogous to that of the viscosity of fluids; it causes losses in motive power and thus reduces the efficiency of the heating operations.

Moreover, this thermal conductivity plays another altogether different and not less harmful part: It causes external heat losses across the walls of the apparatus, and inside the apparatus it causes irreversible drops of heat between regions of different temperatures. This cause of waste does not exist in our hydraulic machines, because their walls consist of iron, a metal impermeable to water, but it would likewise occur if we should use walls of

porous mineral which allows water to escape, in the same manner as heat escapes through the walls of the furnaces.

When, in the preliminary study, we try to abstract the heat from the passive resistances, we meet with a peculiar difficulty resulting from the double part played by the thermal conductivity. On the one hand we must assume that the thermal conductivity is infinitely great between the heating body and the heated body, in order to do away with the resistances offered to the interchange of heat. On the other hand we must assume it to be equal to naught in the furnace wall, or between the different regions of the same furnace. In the instance of shaft furnaces, this leads to the paradoxical hypothesis of an infinitely large conductivity in the horizontal direction and the conductivity zero in the vertical. These are unattainable extreme conditions, but they may be approached more or less, and thus the efficiency may be increased. In the case of a 10-meter high lime kiln charged with bricks of 1-decimeter size, it is obvious that the heat interchange between the hot gases and the bricks occurs more rapidly than between the horizontal cross sections which are separated by the entire height of the kiln. If the kiln were charged with bricks of the size of grains of lead, we would attain an infinitely large horizontal conductivity, but then no mechanical circulation of the gases would be possible.

Shaft Furnace

In continuation of our discussion of the theory of heat, we shall, at this point, make the subject of our study the most perfected apparatus, whose efficiency is the highest but whose operation is also the most complicated: The shaft furnace, i. e. lime kilns, blast furnaces, cupolas for melting etc. Diagrammatically these apparatus may be represented by a vertical cylinder at the top of which there constantly arrives the solid materials to be treated; limestone, iron ores, fuel, etc., while the finished products, lime, iron, slag, leave at the bottom in a similarly continuous manner. Simultaneously, a current of gases passes through the apparatus in the opposite direction. Hot gases, or merely a current of air, enter through the base, and the products of combustion, the fumes, leave by the top. In these apparatus, the hot gases entering through the base meet the materials heated in the higher parts of the furnace by already chilled gases, so that the difference in

temperature between the heating body and the heated body is everywhere reduced, and we thus approach conditions of perfect reversibility, where the interchanges of heat will occur between bodies of equal temperature. This increases the calorific efficiency of these apparatus, the maximum efficiency corresponding to complete reversibility.

Calcination of Quartz

We shall study here the different types of shaft furnaces and at first disregard the passive resistances. We shall start with the simplest cases. Let us consider first the case of the burning of quartz, an operation used in the ceramic industry to facilitate the crushing of quartz. Let us assume that the combustion of the coal takes place externally in the alendiers, while the hot combustion gases enter by the base of the shaft furnace.

Let P be the mass of solid materials passing through a horizontal cross section of the furnace in the unit of time,
C be the average specific heat of their unit of mass (kilogram or mole),
T be their temperature in degrees Cent.,
T_o being the entrance temperature at the top of the furnace, and
T_n the end temperature when leaving at the base of the furnace.

Let the corresponding units for the gases be: p, c, t_o, and t_n for the masses, specific heats, and temperatures. Since the gases enter by the base of the furnace, t_o corresponds to the temperature at the base, and t_n to the temperature at the top of the furnace.

The problem to be solved consists in determining the law of temperature distribution in the furnace and, in particular, the end temperature T_n of the finished material and the end temperature t_n of the fumes, both as functions of the given quantities of the operation, viz. the masses P and p, the specific heats C and c, and the entrance temperatures T_o and t_o.

Temperature Distribution in the Furnace

If we assume, in order to eliminate the passive resistances, that the heat interchange between the two currents of matter occurs very rapidly, or even instantaneously, we must conclude that the materials passing through one horizontal furnace cross

section in opposite directions,—gases as well as solids,—have the same temperature. Let T_1 and T_2 be the temperatures at two different cross sections. Now let us apply the principle of conservation of energy to the heat interchange which may possibly occur between the two sections. In an actual case where there is no interference from any mechanical or electrical phenomenon, this principle may be stated as follows:

"The sum of the quantities of heat absorbed or liberated,—i. e. obtained from or imparted to the outside—, by a system that passes from an initial well-determined state to another state equally well determined, depends only on these two extreme states, and is independent of the intermediate states passed through."

Let us mentally isolate the volume of the furnace between the two sections with temperatures T_1 and T_2, and let us assume that the initial state be that of the materials entering the above volume with their actual temperature, and as the final state that of the materials leaving the same volume and reduced to the temperature of melting ice, say 0 degrees.

We will then have:

$$PCT_1 + pcT_2 = PCT_2 + pcT_1$$

$$\text{or} \qquad (PC - pc)\ (T_1 - T_2) = 0 \qquad (1)$$

In the general case, where PC is different from pc, this equation can only be satisfied for: $T_1 = T_2$, which means that the temperature is uniform from the base to the top of the furnace. The heat interchange then takes place at the free surface of the top or the bottom of the furnace. The thickness of this zone of temperature change is infinitely small of the first order. We have to consider it as formed by the superposition of infinitely thin sections of the second order, in which sections take place the successive changes of heat necessary in the reversibility of the phenomenon. This uniformity of heat is a very important fact which we will have to use in the following. In the case where the specific heats of the two currents of matter are equal to each other, the distribution of the temperature in the furnace is indeterminate.

End Temperature of Materials

The application of the principle of conservation of energy to the initial state of the materials before their entrance into

the furnace and the final state after leaving it, furnishes a fundamental relationship between the temperatures at which the two currents of materials passing through the furnace leave it. This relationship is, by the way, independent of the reversibility and consequently of the hypotheses based on the thermal conductivity. This relation is:

$$PCT_o + pct_o = PCT_n + pct_n$$

which can be put in the form:

$$\frac{T_n}{\Theta} + \frac{t_n}{\Theta} = 1 \qquad (2)$$

if we make:

$$\Theta = \frac{PCT_o + pct_o}{PC}, \text{ and } \Theta = \frac{PCT_o + pct_o}{pc}$$

The ratio of Θ to Θ is therefore the inverse of the ratio of PC to pc.

We can represent the equation (2) graphically by a straight line that cuts the axis of the abscissae T_n at the point Θ and the axis of the ordinate t_n at the point Θ. This straight line necessarily passes through the point defined by the co-ordinates corresponding to the initial temperatures: $T_n = T_o$, and $t_n = t_o$.

The Figs. 1, 2 and 3 relate to the cases where pc is larger, equal to, or smaller than PC, the straight line being inclined at an angle of 45 degrees for the case of equality.

All the temperature couples corresponding to each point of the straight line satisfy the principle of the conservation of energy, but only one of these points can be effectively used. In order to determine it, it is necessary to interpose a new law which may be regarded as belonging to the principle of the dissipation of energy, but shall rather be considered as an empiric, independent law:

"In all exchanges of heat caused exclusively by conductivity, convection or radiation,—i. e., in absence of all mechanical, electrical or chemical phenomena—, it is impossible to heat a body to a higher temperature or to cool it to a lower temperature than that of the hottest or coldest body of the initial system."

According to this law, the only useful part of the straight

line is the segment AB within the rectangle formed by the following four co-ordinates:

$$T_n = T_o\ ,\quad T_n = t_o\ ,\quad t_n = t_o\ ,\text{ and }\quad t_n = T_o.$$

We might mention here that every natural system deprived of passive resistances tends toward the state corresponding to the

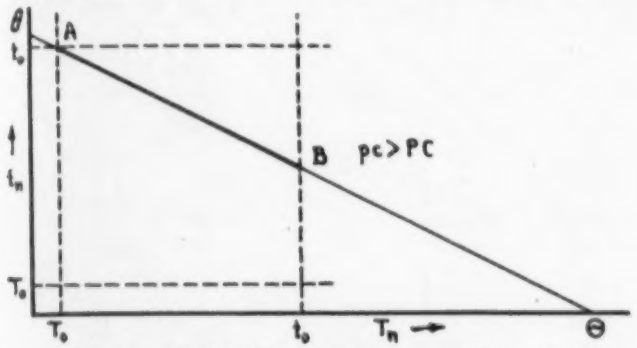

Fig. 1—Graphic Representation of Equation 2 Where pc is Larger Than PC.

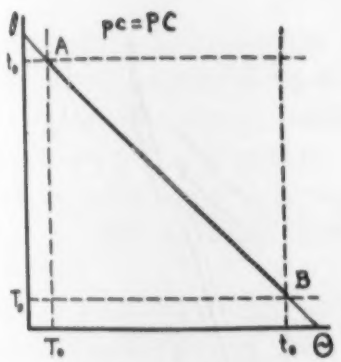

Fig. 2—Graphic Representation of Equation 2 Where pc is Equal to PC.

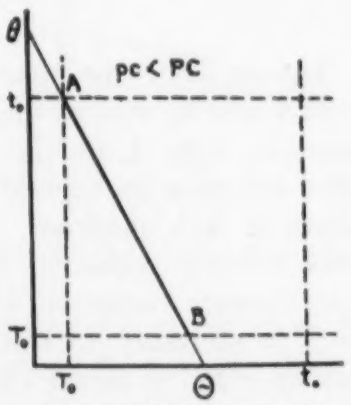

Fig. 3—Graphic Representation of Equation 2 Where pc is Smaller Than PC.

greatest expenditure of motive power and prove that under actual conditions this final state corresponds to the lowest point of the useful part of the straight line, viz. the point B.

We can reach the same conclusion by a simpler reasoning, namely by applying to the interior zones of the furnace the law of limitation of temperature: At no point can the temperature be higher or lower than that of the hottest or coldest body entering the furnace, it always being understood that no other phenomenon takes place in the furnace with the exception of direct exchanges of heat.

Let a horizontal cross section of the interior of the furnace have the temperature T_1. Now let us apply the principle of the conservation of energy to the materials passing through the volume between this cross section and the top or the bottom of the furnace.

Top of furnace.

$$PCT_o + pcT_1 = PCT_1 + pct_n$$

or $$\frac{T_1}{\varphi} + \frac{t_n}{\Theta'} = 1 \qquad (3)$$

Bottom of furnace.

$$PCT_1 + pct_o = PCT_n + pcT_1$$

$$\frac{T_n}{\Theta'} + \frac{T_1}{\varphi'} = 1 \qquad (4)$$

by placing:

$$\Theta' = \frac{PCT_o}{pc}$$

and $$\varphi = \frac{PCT_o}{PC - pc}$$

$$\varphi' = \frac{pct_o}{pc - PC}$$

and $$\ldots = \frac{pct_o}{PC}$$

Let us draw the straight lines representing these equations (Figs. 4 and 5) and at the same time prolong the axes of the ordinates in Figs. 1 and 3. The lengths starting from the origin of the ordinates and away from the origin may be considered as positive in each quadrant. The upper quadrants refer to the top of the furnace (equation 3), the lower quadrants to the bottom of the furnace (equation 4).

It is necessary to distinguish two different cases according to whether PC is larger or smaller than pc. This difference results in a change of direction of the slopes of these straight lines. We will finally draw, in each of the quadrants, the ordinates corresponding to the temperatures of the two materials at their entrance into the furnace. The squares thus obtained limit the conceivable temperatures.

When PC is larger than pc, the straight line (equation 3) is completely outside the square, except for a single point of this straight line coinciding with an apex of the square. This is the only one conceivable. Therefore, if PC is greater than pc, this leads to the equation:

$$t_n = T_o$$

When pc is greater than PC, the straight line (equation 4) is completely outside of the square, except for the single point of this line coinciding with an apex of the square. This is the only

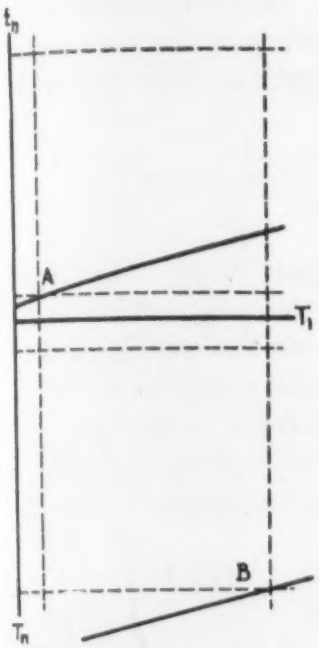

Fig. 4—Case of pc > PC = 1.25 PC.

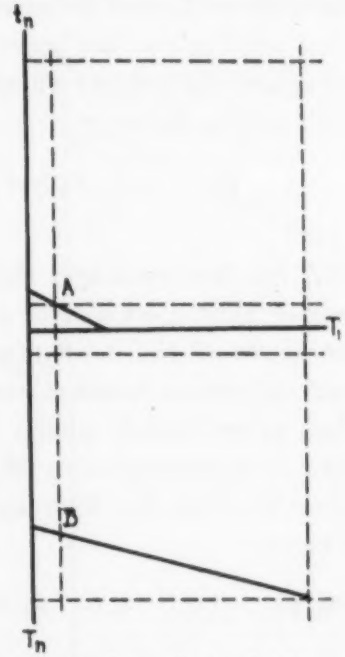

Fig. 5—Case of pc < PC = 0.75 PC.

conceivable point and leads therefore to the equation; $T_n = t_o$ for pc is greater than PC.

In every case the solution of the problem is therefore given by the point B, i. e. by the lowest point of the straight line.

The Temperature Inside the Furnace

We have previously established the fact that the temperature is uniform inside the furnace, while the exchanges of temperature occur in the infinitely thin sections of the top or the bottom of the furnace. It is therefore sufficient to know the temperature at any point of the furnace. Equations (3) and (4) give immediately an answer if we substitute the just determined values for T_n and t_n:

$$\text{For} \quad PC > pc \quad : \quad T_1 = T_o .$$
$$\text{for} \quad pc > PC \quad : \quad T_1 = t_o .$$

To summarize: When the specific heat of the solid materials

is greater than that of the gases, then the end temperature of the gas and that of the entire furnace are equal to the entrance temperature of the cold solid material. This means that the furnace is cold over its entire height. The temperature at which the hot solid materials leave at the bottom of the furnace is given by equation (2) if we substitute T_o for t_n. This means that for PC > pc we have:

$$T_1 = t_n = T_o \text{ and } T_n = T_o + \frac{PC}{pc}(t_o - T_o).$$

If, on the contrary, the specific heat of the current of gases is greater than that of the current of the solid materials, then the temperature of the solid materials at the base of the furnace and that of the entire furnace are equal to the entrance temperature of the hot gases, which means that the furnace is hot over its entire height. The temperature of the gases on leaving at the top of the furnace is given by formula (2) by substituting t_o for T_n. We have then:

$$\text{For } pc > PC: \quad T_1 = T_n = t_o, \text{ and } t_n = t_o - \frac{PC}{pc}(t_o - T_o).$$

The Melting Cupola

Let us assume that we wish to melt iron in a cupola by admitting at the base hot gases from the combustion of coal burned in an independent furnace. The problem differs from the preceding one in the following circumstances: At the moment of melting there occurs an absorption of latent heat which adds itself on to the heat absorbed in the course of simple heating, the latter heat depending only on the specific heats. In addition the melting process introduces a supplementary and very important condition: The heat necessary for melting must be supplied at a temperature which is at least equal to the melting temperature. Finally the melting causes a third zone of discontinuity in the furnace which is added to those at the point of entrance and leaving of the materials (Fig. 6).

In the interval between the zones of discontinuity the temperature is uniform for the reasons stated above and equal to that of the hot gases arriving from the lower zone or that of the solid materials descending from the upper zone, according to whether

the specific heat of the current of gases, pc, is larger or smaller than the specific heat of the current of solid materials, PC. In order to simplify writing without changing the line of reasoning, let us admit that the heated material has the same specific

Fig. 6—Diagram of Melting Cupola.

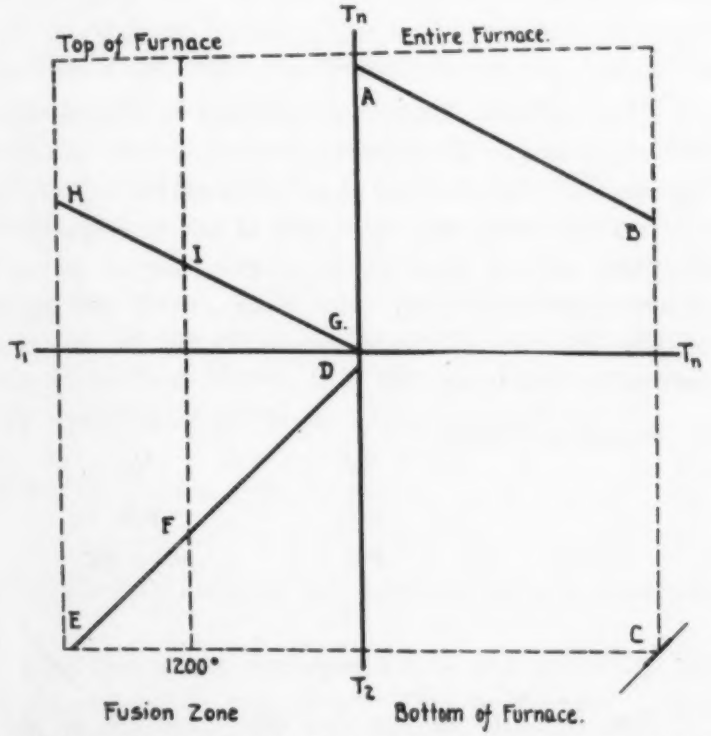

Fig. 7—Straight Line Representing Equation 5.

heat in the solid state as in the liquid state. We shall retain the preceding designations for the entrance temperature of the materials, namely T_o and t_o, and for the end temperatures: T_n and t_n.

Finally let Q be the heat of melting per unit of mass, T_1 be the furnace temperature above the melting zone, and T_2 be the furnace temperature below the melting zone.

Let us finally give specific values to the following data:

$$T_o = 0,\ t_o = 2000 \text{ degrees},\ pc = 2PC,\ Q = -100C$$

The diagram of the curves has been drawn with these data.

As before we shall apply the principle of the conservation of energy to the entire furnace, then to the passage through each zone of discontinuity, successively.

1. Entire furnace.

$$\frac{T_n}{\frac{PCT_o + pct_o + PQ}{PC}} + \frac{t_n}{\frac{PCT_o + pct_o + PQ}{pc}} = 1 \qquad (5)$$

$$\frac{T_n}{3900} + \frac{t_n}{1950} = 1$$

The straight lines representing this equation (Fig. 7) shows the same angle of slope as if there were no melting. With the increase of the melting heat it is shifted lower parallel to itself. At the same time the low point B on the parallel to the axis of the ordinate at the distance t_o in the case of pc is greater than PC moves downward and may pass on to the parallel to the axis of the abscissa at the distance T_o as in the case of no melting and pc is less than PC.

2. Bottom of furnace.

$$\frac{T_n}{\frac{pct_o}{PC}} + \frac{T_2}{\frac{pct_o}{pc - PC}} = 1 \qquad (6)$$

$$\frac{T_n}{4000} + \frac{T_2}{4000} = 1$$

The equality of the two denominators is the outcome of the particular value chosen for the ratio of pc to PC.

3. Melting zone.

$$\frac{-T_2}{\frac{PQ}{pc - PC}} + \frac{T_1}{\frac{PQ}{pc - PC}} = 1 \qquad (7)$$

$$\frac{T_2}{100} - \frac{T_1}{100} = 1$$

4. Top of furnace.

$$\frac{-T_1}{\frac{PCT_o}{pc - PC}} + \frac{t_n}{\frac{PCT_o}{pc}} = 1 \qquad (8)$$

$$T_1 = 2t_n$$

In order to represent these four equations let the axes of the co-ordinates divide the plane into four quadrants, and let us

consider in each quadrant all values away from the origin as positive.

Two conditions limit the temperatures. They must at no point exceed that of the hottest entering material, or the 2000 degrees Cent. of the gas temperature, further the temperature above the melting zone must be at least equal to the melting temperature of iron, or 1200 degrees Cent. In the present example, using the selected data, the second condition is amply satisfied. When solving the equations we find that the molten iron leaves at 2000 degrees Cent. and the hot gases at the furnace top at 950 degrees Cent. The condition referring to the melting temperature comes into play if the line (7) is displaced in such a way that the value of T_1 corresponding to t_n falls below 1200 degrees Cent., or, in the graph, it passes to the right of the point for 1200 degrees Cent. A simple calculation shows that the condition necessary in order to obtain melting is given by the nonequation:

$$\frac{PQ}{pc - PC} < t_o - T_f$$

wherein T_f stands for the melting temperature of the substance in question.

In the case that the above nonequation is not satisfied, only a part of the solid substance will melt. The proportion x thus melted is given by the equation:

$$\frac{xPQ}{pc - PC} = t_o - T_f$$

In order to facilitate the reasoning, we have supposed that the melting zone is somewhere about the middle of the furnace. In reality its position is not arbitrary; it is completely determined by the conditions of the problem. In the numerical example chosen, the temperature T_1 being considerably greater than that of the fusion of the iron, the melting zone will rise progressively until it becomes identical with the top zone where the solid material enters. In this case again, the furnace will be hot for its entire height.

Parallel Co-Ordinates

We have used common rectangular or Cartesian co-ordinates

for the geometrical representation of the equations which express the principle of the conservation of energy. Parallel or nomographic co-ordinates permit, however, an easier discussion of the different problems presented in the study of shaft furnaces.

Let us recall the principle of these two geometric representations. Let us take an equation of the first degree with two variables x and y in the form:

$$\frac{x}{a} + \frac{y}{b} = 1.$$

In parallel co-ordinates this equation is represented by a straight line that intercepts the x-axis at a distance a from the origin, and the y-axis at a distance b.

In parallel co-ordinates this equation is represented by a point. Assume two parallel axes and one of their common perpendiculars the base of which determines on each axis the origin of x and y. We determine the point by going on the x-axis a distance a and on the y-axis a distance b, then we join the extreme point of each of these segments to the zero-point of the other axis. The intersection of these two lines gives the point desired. Every straight line which passes through this point intercepts the two axes at points having such distances x and y from the perpendicular as will satisfy the above equation.

Fig. 8 thus represents the equations for the cupola with the numerical data used in the above example.

The representative point for the bottom of the furnace is located at B, for the melting zone it is at infinity in the direction of the line FF′, and finally for the top of the furnace it is at H.

In order to determine the temperatures of the different zones, we start with the temperature T_n at which the materials leave, which we know to be equal to that at which the hot gases enter, say 2000 degrees Cent. Joining point T_n and prolonging the line, we get point T_2, likewise at 2000 degrees Cent. Through T_2 we draw a line parallel to FF′ and we find for T_1 the temperature of 1900 degrees Cent.; finally, joining T_1 and H we find $t_n = 950$ degrees Cent. as the temperature at which the hot gases leave.

Suppose that we now propose to find such an entrance tem-

perature of hot gases as would be just sufficient to cause the complete melting of the iron, while leaving the mass of the hot gases unchanged. We start with $T_1 = 900$ degrees Cent., then join this

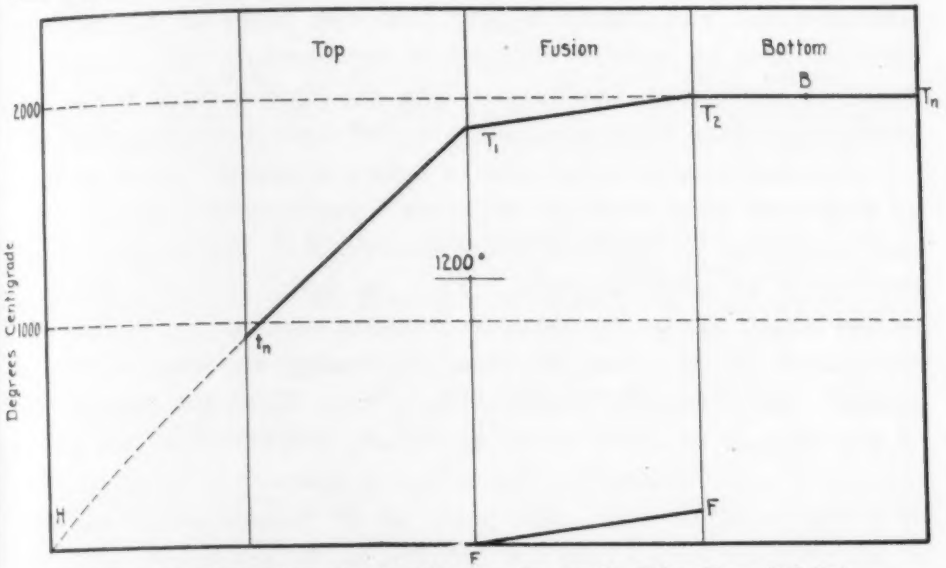

Fig. 8—Lines Representing the Equations for the Cupola, Using Numerical Data.

point with H, and draw a line through it parallel to FF′. We thus obtain T_2 and T_n equal to 1300 degrees Cent. and t_n equal to 600 degrees Cent.

Disturbances

As a matter of fact the theoretical conditions assumed in these calculations are not completely realized in practice. Passive resistances and various other conditions enter and modify the operation of the furnaces. The equations for the conservation of energy will always hold good, but the point on each line corresponding to the temperatures actually obtained are not necessarily the lowest (in Cartesian co-ordinates).

There are three causes of disturbance to be taken into account:

1. The furnace walls are not impermeable to heat. We must therefore introduce into the equations for the conservation of energy a term for this loss of heat. This gives an equation of the same form as that where the melting heat figures. But in this case there is no discontinuity, the heat is lost over the entire height of the furnace. The result is that the temperature is not

uniform from top to bottom of each zone but varies progressively.

2. The conductivity is not infinitely great and the interchange of heat between the two currents of materials is not instantaneous. The result is first that the zones of discontinuity characterized by sudden changes of temperature are replaced by zones of increasing thickness where the temperature varies progressively. This changes nothing in the above derived conclusions.

Furthermore, a loss of motive power is caused by abrupt drops in heat that exist between different temperatures because of the time necessary to establish the equilibrium of temperature within the lumps of solid material. This, in turn, causes a limitation in the extent of the temperature regions that can be utilized and are shown on the straight lines expressing the conservation of energy. In industrial furnaces, however, where the specific heat of the current of gases is always much greater than that of the current of solid materials, this effect is lessened to a large extent by a compensation that takes place, at the instant of the entrance of the solid materials into the furnace, between the inevitable sudden change in heat even in the absence of all passive resistance and the drops in heat due to passive resistances. This second effect increases in the same measure as the first one decreases. Finally, the intervention of passive resistances is generally not an important cause of efficiency reduction.

3. We implied in all our reasoning that the two opposite currents of material move with the same speed in all parts of each horizontal cross section, and that, consequently, temperature wields uniform power over all points of each cross section. In practice things are entirely different, and this is the most important cause of the reduction of the thermal efficiency in shaft furnaces.

Not all the fragments of solid materials have the same dimensions and there are consequently empty spaces between them. The smaller these empty spaces, the smaller the speed of the current of gases. On the other hand the solid materials pressed against the wall are not as closely intermingled as at the center of the charge. The particles touch the walls only with their sharp points and leave relatively large empty spaces between themselves and the wall.

This effect is very pronounced in furnaces where the solid fuel is mixed with the material which is to be heat treated, as

(Continued on Page 602)

LOCOMOTIVE FORGING STEELS

By O. V. Greene

Abstract

The author gives the results of tests made on various types of heat treated alloy steels for reciprocating locomotive parts. Many difficulties have been encountered with complex alloy steels and quenched and tempered carbon steel used for locomotive forgings. As a result many railroads are using normalized steel for their forgings. The normalized forging steel tends to eliminate internal fissures and cracks, internal strains, ferritic segregation due to nonmetallic impurities. If weight is an important factor, however, such steels as vanadium or manganese are used so that sections may be safely reduced in size.

DURING recent years the power requirements of railroads have increased tremendously. The increased weight of both passenger and freight trains has necessitated heavier, larger locomotives capable of developing greater horsepower. Since horsepower is the product of the tractive force and the speed, it is not uncommon to find passenger locomotives developing a horsepower equal to that of freight locomotives. In general with passenger locomotives a comparatively low tractive force with high speed is developed, while a freight locomotive is designed for higher tractive force and low speed. Thus to meet present day traffic demands, the capacities of locomotives have been increased in both classes of service, with higher speeds in the former and greater weights in the latter.

Alloy Steel

As a consequence the design and requirements of locomotives today have taxed engineering materials to the utmost. Engine designers have realized that the locomotive forging steels of ten or fifteen years ago cannot fulfill requirements of today. For this reason experiments have been conducted with various types of heat treated alloy steels for connecting rods, crank pins, piston

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rods and other reciprocating parts. For example, steels such as the following have been experimented with:

S. A. E. 2330 and 2335 (C 0.25 to 0.35 per cent and 0.30 to 0.40 per cent respectively, Ni 3.25 to 3.75 per cent).

S. A. E. 3135 and 3140 (C 0.30 to 0.40 per cent and 0.35 to 0.45 per cent respectively, Ni 1.00 to 1.50 per cent, and Cr 0.45 to 0.75 per cent).

The tensile properties obtained with these steels were quite good. For instance, a steel conforming to S. A. E. 3140, forged into connecting rods, quenched at 1550 degrees Fahr. and tempered at 1200 degrees Fahr. gave the following results:

	Average of 20 Tests	Maximum	Minimum
Elastic Limit	58,300 Lbs. per in.^{2}	75,000 Lbs. per in.^{2}	55,000 Lbs. per in.^{2}
Ultimate Strength	103,000 Lbs. per in.^{2}	118,000 Lbs. per in.^{2}	90,000 Lbs. per in.^{2}
Elongation in 2" .	22.2 per cent	26.0 per cent	20.5 per cent
Reduction of Area	50.2 per cent	60.8 per cent	46.8 per cent

The results of practically every service test with such material, however, were unsatisfactory. The reasons for this were numerous. The alloy steel ingots were as a rule not large enough to have billets of the required amount of reduction manufactured from them. Also the forgings were so large that it was nearly impossible to obtain uniform physical properties throughout the section after heat treatment. Of course these same steels are excellent for heat treated automobile forgings, as the sections are small enough for the heat treatment to be nearly ideal. If the mass and section of a connecting rod, weighing from 1500 to 2150 pounds, be compared to an automobile crank shaft or axle, the difficulties encountered in the heat treatment will be obvious. Finally, although it has not been definitely proven, there have been a sufficient number of cases to warrant the belief that if the surface finish on steels of this type is not the best obtainable, the fatigue strength is greatly lowered as compared to ordinary carbon steel with the same finish. There have also been sufficient cases that lead to the belief that the presence of cracks and nicks caused by accidental blows, grooves caused by wear, and shoulders with short radius fillets have a more marked effect on the lowering of the fatigue strength of such alloy steels when applied to locomotive forgings, than on ordinary carbon steel.

Examples of this last mentioned type of failure are familiar

to every railroad mechanical engineer or engineer of tests. Fig. 1 shows a failure due to change of cross section and localization of stress on a rectangular section side rod. The scoring extended practically the full length of the section, becoming deepest at the

Fig. 1—Photograph Showing Failure Due to Scoring on the Side of a Rectangular Section Side Rod. Approximately One-Half Size. Figs. 2 and 3—Showing Cracks in the Heads of an I-Section Side Rod Resulting from a Nick and a Hammer Dent, Respectively. ½ Size.

edge where detailed fracture began. The subsequent failure of such a reciprocating stress member was only a matter of a short time. Figs. 2 and 3 show cracks on the heads of I-section side rods developing from a nick and a hammer dent respectively. These cracks of course would have rapidly led to total failure of the member. Incidentally Fig. 3 is a nickel-chromium rod, having 0.43 per cent carbon, 1.30 per cent nickel and 0.63 per cent chromium.

Quenched and Tempered Steel

In the past to obtain the necessary physical properties ordinary open-hearth carbon steel locomotive forgings were quenched and tempered. Most of these steels fall within the following chemical specifications:

	Per Cent
Carbon	0.40 to 0.60
Manganese	0.45 to 0.70
Phosphorus	0.045 Max.
Sulphur	0.05 Max.

The heat treatment was approximately as follows: The steel was allowed to become cool after forging. It was then reheated uniformly between 1550 and 1600 degrees Fahr. and quenched in water. Finally after becoming cold, the forgings were heated between 1150 and 1200 degrees Fahr. for the tempering, and were cooled slowly in the furnace. The tensile results of such material forged into connecting rods, driving axles, crank pins and piston rods and heat treated as above, are as follows:

	Average of 35 Tests	Maximum	Minimum
Elastic Limit	63,300 Lbs. per in.^{2}	72,000 Lbs. per in.^{2}	52,000 Lbs. per in.^{2}
Ultimate Strength	103,500 Lbs. per in.^{2}	113,000 Lbs. per in.^{2}	95,500 Lbs. per in.^{2}
Elongation in 2" .	22.3 per cent	26.0 per cent	20.0 per cent
Reduction of Area	54.0 per cent	60.1 per cent	49.5 per cent

Fig. 4 shows the structure typical of such quenched and tempered steel. The sample was taken from a driving axle 12 inches in diameter with the following analysis. C 0.587 per cent, Mn 0.620 per cent, P 0.020 per cent, S 0.041 per cent, Si 0.240 per cent, and had the following physical properties:

Elastic Limit	65,000 Lbs. per in.^{2}
Ultimate Strength	104,500 Lbs. per in.^{2}
Elongation in 2 inches	24.0 per cent
Reduction of Area	55.5 per cent

While quenched and tempered carbon steel has the tensile properties required by the specification, such forgings fall considerably short of being an ideal material. Because of the large mass of metal in most of these forgings, high internal strains are set up on quenching. Subsequent tempering apparently does not always relieve all these strains. Consequently quite often a forging is applied to a locomotive in a highly internally stressed condition. Another grave danger with quenched and tempered steels is the amount and segregation of the nonmetallic inclusions.

Fig. 5 shows the amount of nonmetallics contained in the cross section of a driving axle. Such amounts of inclusions are commonly encountered. Often the amounts shown here are exceeded. Internal rupture often occurs on quenching when a steel contains like amounts of inclusions, sufficiently segregated. Fig. 6 shows internal quenching cracks following inclusions in the cross section of a driving axle. In some cases these fissures extend to the surface and in others they are entirely on the inside. When the former takes place the cracks can be quite easily detected.

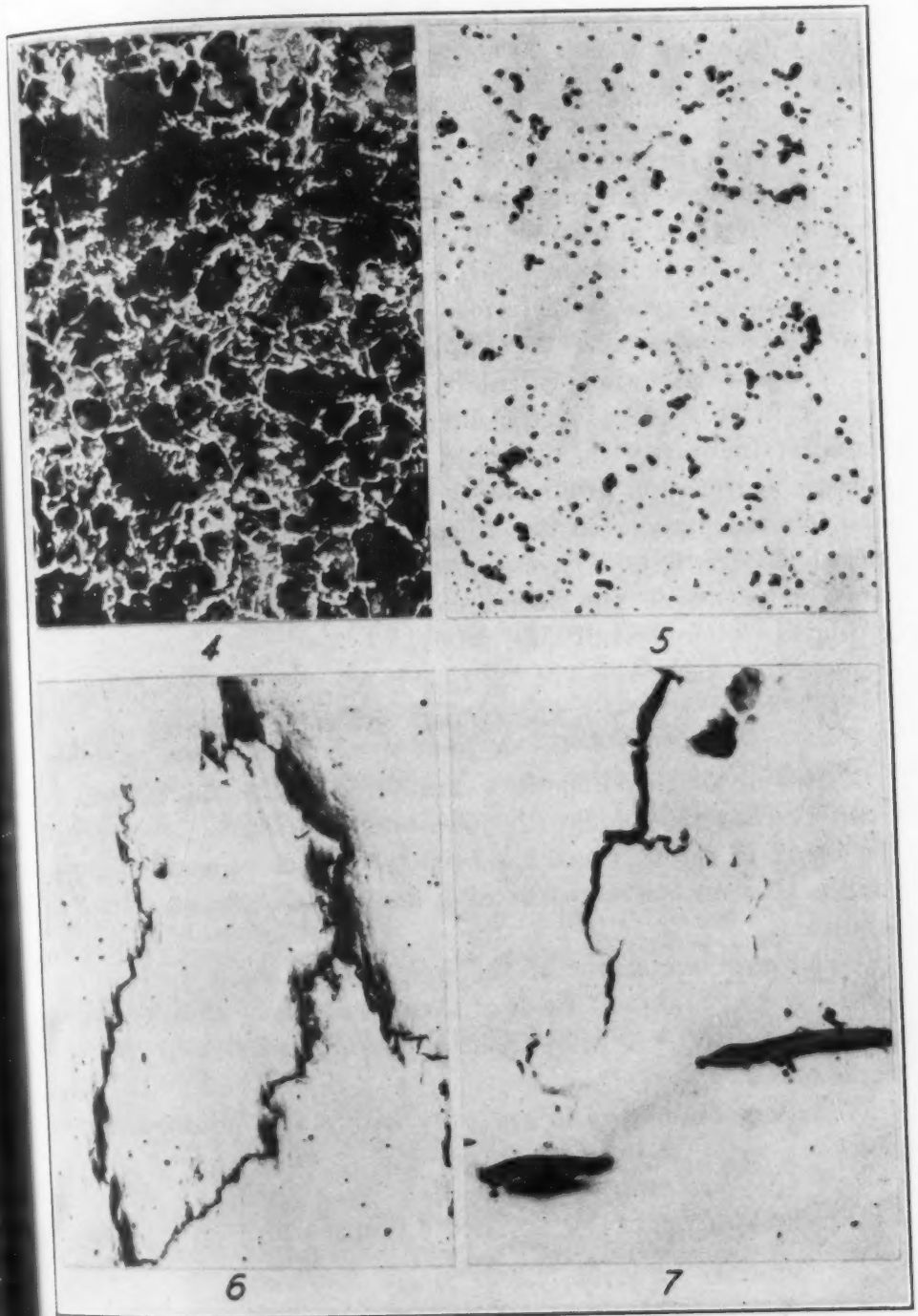

Fig. 4—Photomicrograph Showing Typical Structure of Quenched and Tempered Driving Axle. Carbon, 0.587 Per Cent; Manganese, 0.620 Per Cent; Magnification 100 x. Fig. 5—Photomicrograph Showing Nonmetallic Inclusions Contained in the Cross Section of a Driving Axle. Magnification 100 x. Fig. 6—Photomicrograph Showing Internal Quenching Cracks Following Inclusions in the Cross-Section of an Axle. Magnification 100 x. Fig. 7—Photomicrograph of a Fatigue Crack Developed by the Aid of Inclusions. Longitudinal Section. Magnification 250 x.

However, if the latter is the case no ordinary method of inspection will reveal them. When forgings containing such internal ruptures are placed in service, disastrous results are always encountered.

The presence of undesirable amounts of nonmetallic impurities also accelerates the speed of fatigue failure. Fig. 7 shows the end of a fatigue crack in a driving axle. The path of the fissure is seen to be branching and developing by the aid of the inclusions. The use of inclusions in the development of a fatigue crack, so well described as "stepping stones" in a recent paper by F. F. Lucas, is quite evident here.

A further effect of the amount and segregation of the nonmetallic inclusions in quenched and tempered material, is the ferritic segregation around or near the impurities. Fig. 8 shows the ferritic segregation due to inclusions in a quenched and tempered driving axle. This condition is not particularly desirable since it results in the heterogeneous structure composed of soft stringers in a relatively hard matrix.

Normalized Steel

Because of the difficulties encountered with the more or less complex alloy steel and with quenched and tempered carbon steel, the trend in recent years has been to use for railroad forgings a simple alloy or carbon steel in a double annealed or normalized condition.

The most important of the simple alloy steels used are manganese and vanadium. Each of these steels have advantages peculiar to it alone. A comparison of the properties of these two steels follows:

The vanadium steel is generally within the following chemical limits:

	Per Cent
Carbon	0.45 to 0.55
Manganese	0.70 to 0.90
Sulphur	0.040 Max.
Phosphorus	0.040 Max.
Silicon	0.15 to 0.25
Vanadium	0.19 Min.
Chromium	0.20 Max.

This steel is usually treated by normalizing and reheating.

It is normalized at 1600 to 1650 degrees Fahr. and the forging removed from the furnace and cooled in still air. This is followed by reheating at 1150 to 1250 degrees Fahr. being removed from the furnace and allowed to cool as before. The tensile properties of vanadium steel after this double treatment are as follows:

	Average of 50 Tests	Maximum	Minimum
Elastic Limit	61,500 Lbs. per in.^{2}	72,000 Lbs. per in.^{2}	56,000 Lbs. per in.^{2}
Ultimate Strength	100,000 Lbs. per in.^{2}	113,000 Lbs. per in.^{2}	89,000 Lbs. per in.^{2}
Elongation in 2" .	25.8 per cent	29.0 per cent	22.0 per cent
Reduction of Area	52.5 per cent	61.9 per cent	46.6 per cent

Impact tests made with a V-notched Izod bar gave the following results:

Average of 8 Tests	23.9 foot pounds
Maximum	27.0 foot pounds
Minimum	21.5 foot pounds

The tensile and impact tests were taken from prolongations on connecting rods, crank pins and piston rod forgings.

Fig. 9 shows the average structure of normalized and reheated vanadium steel. This particular specimen was from a side rod that analyzed: carbon 0.585 per cent, manganese 0.929 per cent and vanadium 0.203 per cent. It had the following tensile properties:

Elastic Limit	65,000 Lbs. per in.^{2}
Ultimate Strength	103,000 Lbs. per in.^{2}
Elongation in 2 inches	25.0 per cent
Reduction of Area	51.2 per cent

The manganese steel used falls generally within the following chemical limits:

	Per Cent
Carbon	0.30 to 0.40
Manganese	1.60 to 1.90
Phosphorus	0.040 Max.
Sulphur	0.040 Max.
Silicon	0.15 to 0.25

Examples of manganese steels varying from this analysis will be given later.

Forgings made of manganese steel of this class were treated by normalizing and tempering similar to the vanadium steel. These forgings were normalized from 1500 to 1550 degrees Fahr.

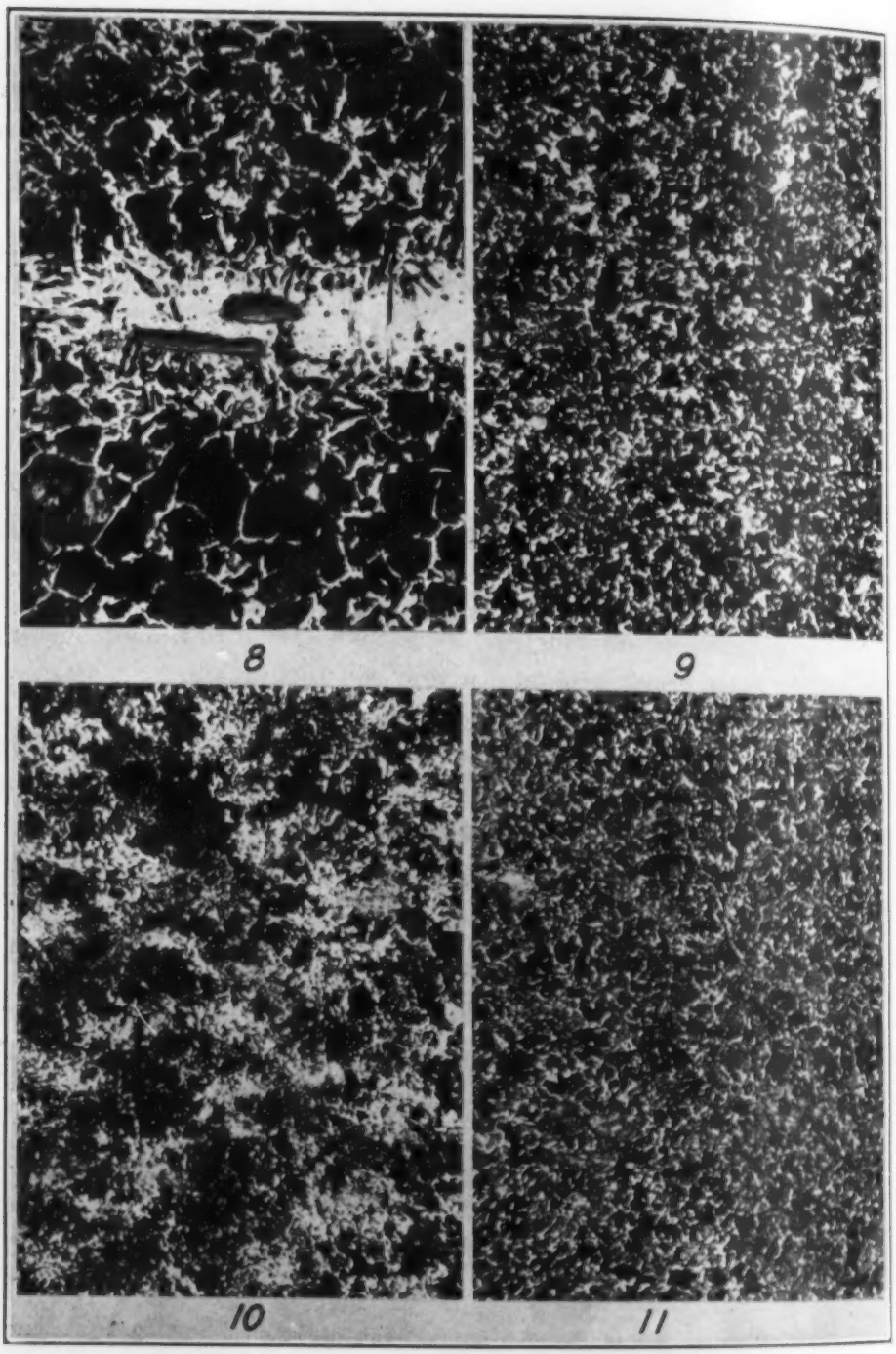

Fig. 8—Photomicrograph of Ferritic Segregation Caused by Segregation of Nonmetallic Inclusions. Longitudinal Section. Magnification 100 x. Fig. 9—Average Structure of Normalized and Reheated Vanadium Steel. Carbon, 0.585 Per Cent; Manganese, 0.929 Per Cent; Vanadium, 0.203 Per Cent. Magnification 100 x. Fig. 10—Photomicrograph Showing the Average Structure of Normalized and Reheated Manganese Steel. Magnification 100 x. Carbon, 0.410 Per Cent; Manganese, 1.88 Per Cent. Fig. 11—Photomicrograph Showing Structure of Manganese Steel Piston Rod. Carbon, 0.428 Per Cent; Manganese, 1.439 Per Cent. Magnification 100 x.

and cooled in still air. They were then reheated from 1050 to 1100 degrees Fahr. and cooled in air as before. The tensile properties after this double treatment are as follows:

	Average of 15 Tests	Maximum	Minimum
Elastic Limit	61,000 Lbs. per in.^{2}	63,500 Lbs. per in.^{2}	51,000 Lbs. per in.^{2}
Ultimate Strength	97,700 Lbs. per in.^{2}	107,000 Lbs. per in.^{2}	86,500 Lbs. per in.^{2}
Elongation in 2" .	27.4 per cent	30.0 per cent	24.0 per cent
Reduction of Area	64.5 per cent	70.1 per cent	49.8 per cent

Impact tests made with V-notched Izod bar gave the following results:

Average of 8 Tests	36.9 foot pounds
Maximum	43.0 foot pounds
Minimum	29.0 foot pounds

The tensile and impact tests were taken from elongations on connecting rods and piston rods.

Fig. 10 shows the structure of normalized and reheated manganese steel of this composition as made into a piston rod with a 6-inch diameter and 1-inch hole. The steel in Fig. 10 analyzed: carbon 0.410 per cent, manganese 1.880 per cent, phosphorus 0.030 per cent, sulphur 0.026 per cent, and had the following physical properties:

Elastic Limit	63,000 Lbs. per in.^{2}
Ultimate Strength	106,000 Lbs. per in.^{2}
Elongation in 2 inches	23.0 per cent
Reduction of Area	61.0 per cent

Steels with a lower manganese content have also been used. Fig. 11 shows the structure of a manganese steel used for a piston rod analyzing: carbon 0.428 per cent, manganese 1.439 per cent, phosphorus 0.025 per cent, sulphur 0.022 per cent, and had the following physical properties after normalizing at 1600 degrees Fahr. and reheating at 1100 degrees Fahr.:

Elastic Limit	62,000 Lbs. per in.^{2}
Ultimate Strength	107,000 Lbs. per in.^{2}
Elongation in 2 inches	26.0 per cent
Reduction of Area	57.0 per cent

Fig. 12 shows a manganese steel used for locomotive driving wheel tires, analyzing: carbon 0.614 per cent, manganese 1.166 per

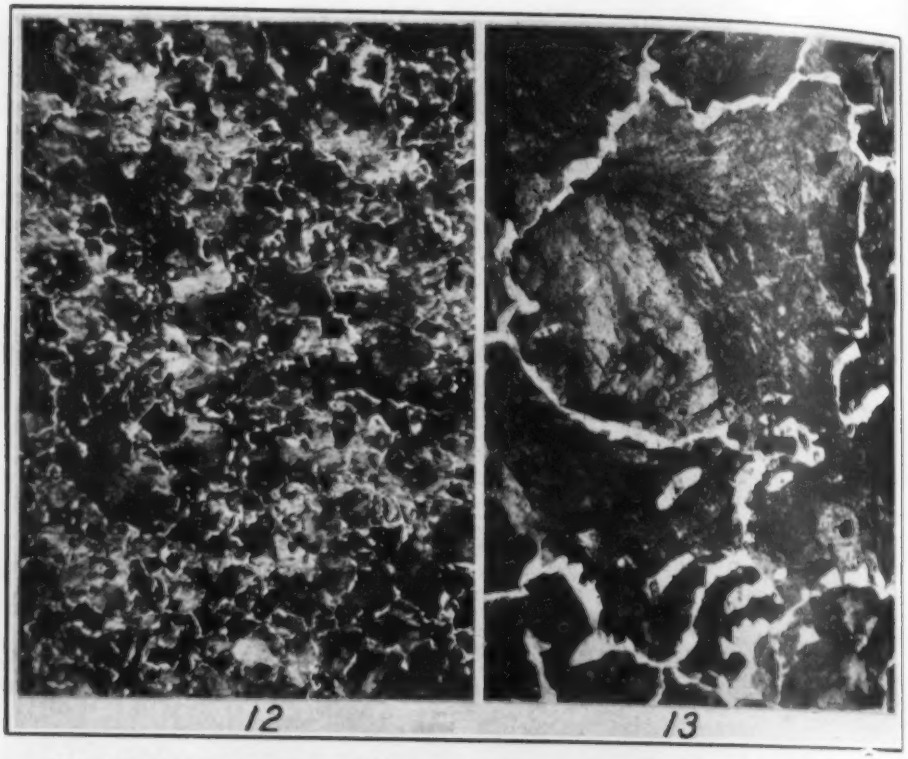

Fig. 12—Photomicrograph Showing the Structure of a Manganese Steel Driving Wheel Tire. Carbon, 0.614 Per Cent; Manganese, 1.166 Per Cent. Magnification 100 x. Specimen Taken from Flange. Fig. 13—Photomicrograph Showing the Structure of Carbon Steel Driving Wheel Tire. Carbon, 0.614 Per Cent; Manganese, 0.683 Per Cent. Specimen Taken from Flange. Magnification 100 x.

cent, phosphorus 0.018 per cent, sulphur 0.043 per cent. This specimen was taken from the flange of a tire. If this be compared to Fig. 13 which was taken from the flange of an ordinary carbon steel tire, analyzing: carbon 0.614 per cent, manganese 0.683 per cent, phosphorus 0.020 per cent, sulphur 0.028 per cent, the use of manganese to produce a steel with a more desirable grain, will be evident.

It is curious to note at this point that a well known writer of metallurgical literature remarks that steel containing over 1.50 per cent of manganese is brittle. Nothing is actually farther from the truth. If the physical results of the manganese forging steels be compared to the vanadium, it is seen that while the manganese steel is lower in elastic limit and ultimate strength, it has a considerably higher elongation, reduction of area, and impact value than the vanadium steel. These advantages of the manganese steel over the vanadium are somewhat offset, however, by several

conditions. Manganese steel has seldom shown the uniformity in structure obtained with the vanadium steel. If Figs. 10 and 16 be compared to Figs. 9 and 17, the nonuniform banded structure peculiar to manganese steel of this composition, will be evident. A manganese steel forging seldom has exactly the same physical properties throughout, independent of any precaution or care taken in the heat treatment. Vanadium forgings on the other hand, almost invariably have identical physical properties throughout. Segregation of nonmetallic impurities producing ferritic segregation in manganese steel is a further undesirable condition. However, it should be noted that the above characteristics are based on only 15 tests from two heats of manganese steel, as compared to 50 tests from six heats of vanadium steel. The following tests are included to amplify these points.

A vanadium and a manganese steel were heat treated at the same time by normalizing from 1550 to 1600 degrees Fahr. and reheated from 1100 to 1150 degrees Fahr. These forgings had approximately the same weight. The analyses of these steels are as follows:

	Vanadium Steel	Manganese Steel
Carbon	0.47 Per Cent	0.321 Per Cent
Manganese	0.84	1.818
Phosphorus	0.028	0.020
Sulphur	0.036	0.022
Silicon	0.20	0.16
Vanadium	0.19	
Chromium	0.05	

Fig. 14 shows the amount of reduction and the condition of the tensile test bars of both the manganese and vanadium steels.

The tensile properties of the manganese steel represented by the tests bars 1, 2, 3, shown in Fig. 14 are as follows:

	1	2	3
Elastic Limit	62,000 Lbs. per in.^{2}	62,000 Lbs. per in.^{2}	63,500 Lbs per in.^{2}
Ultimate Strength	96,000 Lbs. per in.^{2}	97,000 Lbs. per in.^{2}	99,000 Lbs. per in.^{2}
Elongation in 2"	24.5 per cent	28.5 per cent	28.5 per cent
Reduction in Area	49.8 per cent	67.1 per cent	60.7 per cent

The tensile properties of the vanadium steel also represented by test bars 4, 5, 6, in Fig. 14 are as follows:

	4	5	6
Elastic Limit	72,000 Lbs. per in.^{2}	70,500 Lbs. per in.^{2}	70,500 Lbs. per in.^{2}
Ultimate Strength	111,000 Lbs. per in.^{2}	111,000 Lbs. per in.^{2}	111,000 Lbs. per in.^{2}
Elongation in 2"	23.5 per cent	23.0 per cent	23.0 per cent
Reduction of Area	47.0 per cent	46.9 per cent	46.3 per cent

Test bar No. 1 was located in the center of the manganese test elongation. It is typical of the nonuniformity encountered in manganese steels of this analysis. The ragged fracture, the low elongation and reduction of area were due to nonmetallic segregation in the form of stringers.

Fig. 15 shows the amount and condition of the inclusions in

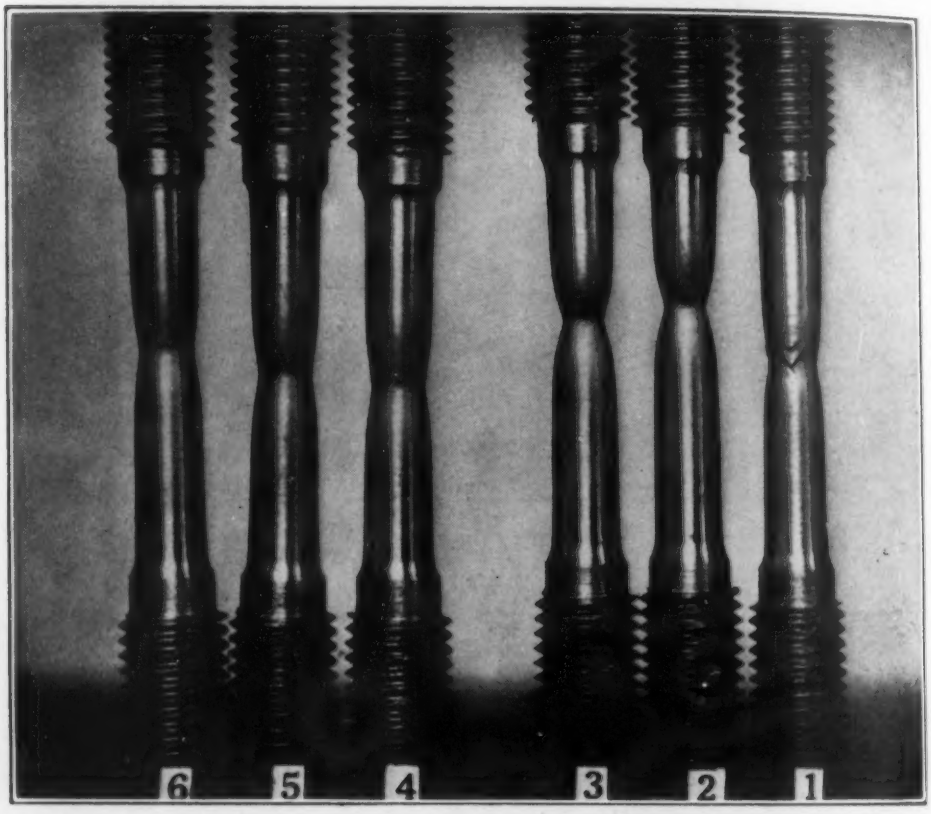

Fig. 14—Photograph of Tensile Test Specimens of Manganese and Vanadium Steels. Bars 1, 2 and 3 are Manganese Steel Normalized and Reheated. Carbon Content, 0.32 Per Cent; Manganese, 1.82 Per Cent. Bars 4, 5 and 6 are Vanadium Steel Normalized and Reheated. Carbon Content, 0.47 Per Cent; Manganese, 0.84 Per Cent; Vanadium, 0.19 Per Cent; Chromium, 0.05 Per Cent.

the longitudinal section of this specimen. Fig. 16 shows the average structure of the manganese steel test bar number 2. Fig. 17 shows the structure of the vanadium steel. This specimen was taken from test bar number 5. If these photomicrographs be compared, the greater uniformity of the vanadium steel will be obvious.

A number of railroads have turned to normalized and reheated (or tempered) carbon steel for their locomotive forgings.

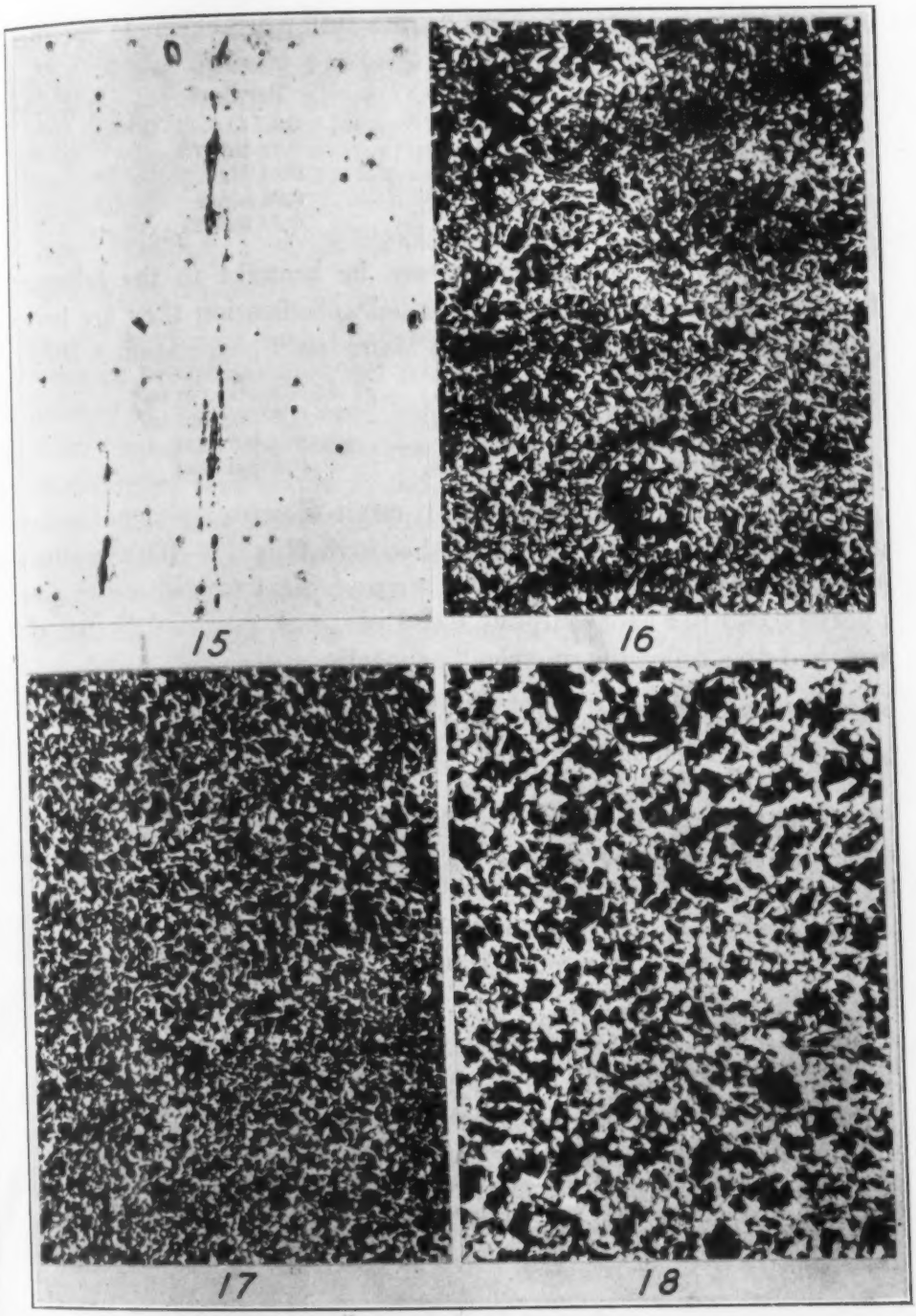

Fig. 15—Photomicrograph Showing the Amount and Condition of Nonmetallic Inclusions in Longitudinal Section of Test Bar No. 1. Magnification 100 x. Fig. 16—Photomicrograph Showing the Structure of Manganese Steel. Cross Section of Test Bar No. 2. Magnification 100 x. Fig. 17—Photomicrograph Showing the Structure of Vanadium Steel. Cross Section of Test Bar No. 5. Magnification 100 x. Fig. 18—Photomicrograph Showing the Structure of Normalized and Tempered Carbon Steel Driving Axle. Carbon, 0.47 Per Cent; Manganese, 0.62 Per Cent. Magnification 100 x.

Such steel is generally bought to the following chemical specification:

	Per Cent
Carbon	0.45 to 0.55
Manganese	0.40 to 0.70
Phosphorus	0.04 Max.
Sulphur	0.04 Max.
Silicon	0.15 to 0.25

Forgings of this character can be brought to the following tensile requirements, but in the usual specification they are lower. (See American Society for Testing Materials, Specification A 20-21).

Elastic Limit	45,000 Lbs. per in.²
Ultimate Strength	85,000 Lbs. per in.²
Elongation in 2 inches	25.0 per cent
Reduction of Area	40.0 per cent

An example of the structure obtained with such material as used in driving axle forgings is shown in Fig. 18. This specimen analyzed: carbon 0.47 per cent, manganese 0.62 per cent, phosphorus 0.040 per cent, sulphur 0.038 per cent, silicon 0.25 per cent and had the following physical properties:

Elastic Limit	53,000 Lbs. per in.²
Ultimate Strength	89,500 Lbs. per in.²
Elongation in 2 inches	25.0 per cent
Reduction of Area	43.5 per cent

The average physical results on various types of forgings made of this material and heat treated by normalizing and reheating are:

Carbon Steel Driving Axles

	Average of 10 Tests	Maximum	Minimum
Elastic Limit	48,100 Lbs. per in.²	49,000 Lbs. per in.²	47,000 Lbs. per in.²
Ultimate Strength	88,200 Lbs. per in.²	90,000 Lbs. per in.²	86,000 Lbs. per in.²
Elongation in 2″	26.5 per cent	30.0 per cent	25.0 per cent
Reduction in Area	46.6 per cent	53.5 per cent	40.5 per cent

Carbon Steel Piston Rods

	Average of 10 Tests	Maximum	Minimum
Elastic Limit	48,800 Lbs. per in.²	52,000 Lbs. per in.²	46,500 Lbs per in.²
Ultimate Strength	89,550 Lbs. per in.²	92,500 Lbs. per in.²	87,000 Lbs. per in.²
Elongation in 2″	26.3 per cent	28.0 per cent	25.0 per cent
Reduction of Area	46.3 per cent	58.5 per cent	40.5 per cent

Carbon Steel Crank Pins

	Average of 11 Tests	Maximum	Minimum
Elastic Limit	47,860 Lbs. per in.²	49,000 Lbs. per in.²	47,000 Lbs. per in.²
Ultimate Strength	86,950 Lbs. per in.²	92,000 Lbs. per in.²	85,500 Lbs. per in.²
Elongation in 2″	26.4 per cent	28.5 per cent	25.0 per cent
Reduction of Area	45.6 per cent	50.0 per cent	40.5 per cent

Carbon Steel Connecting Rods

	Average of 11 Tests	Maximum	Minimum
Elastic Limit	49,450 Lbs. per in.²	53,500 Lbs. per in.²	47,000 Lbs. per in.²
Ultimate Strength	88,500 Lbs. per in.²	93,000 Lbs. per in.²	85,000 Lbs. per in.²
Elongation in 2" .	27.3 per cent	30.0 per cent	25.0 per cent
Reduction of Area	52.5 per cent	57.0 per cent	45.0 per cent

Summary

Due to the difficulties encountered with the complex alloy steels and quenched and tempered carbon steel, many railroads have turned to normalized steel for their locomotive forgings. The advantages of normalized and reheated (tempered) forgings over quenched material are numerous. In a normalized forging the internal fissures and cracks found in quenched material are never present. The magnitude of internal strains found in many of the quenched forgings is never encountered in normalized material with the exception of the manganese forging steels, well-defined ferritic segregation due to nonmetallic impurities is also seldom found in normalized forgings.

Of the simple alloy steels used for normalizing the vanadium steel is slightly better than the manganese steel. This statement is of course based on the author's investigation only. Since his experience with manganese steel has been quite meager as compared with vanadium steel, such a conclusion may be unwarranted. Also it is obvious that these conclusions are based entirely upon laboratory results. In spite of the disquieting characteristics of the manganese steel, such as its segregation of nonmetallics and ferrite, the service results we have obtained to date have been satisfactory.

While the normalized carbon steel forgings do not show physical properties equal to the vanadium and manganese steels, their use is justified since they may be economically and safely applied to all classes of locomotives if the sections are large enough to insure the necessary factor of safety. Of course on a locomotive where weight is important, such steels as vanadium or manganese are employed in order that the sections may be safely reduced in size.

Acknowledgment

The author wishes to acknowledge his indebtedness to J. H. Higgins of the Camden Forge Company, Camden, N. J., for the

results on the various normalized and tempered carbon steel forgings appearing at the end of the paper.

DISCUSSION

Written Discussion: By E. J. Edwards, American Locomotive Company, Schenectady, N. Y.

We are indebted to Mr. Greene for this contribution as it has opened up for discussion a problem which is of vital importance to the public at large, and is a subject which has not received the serious consideration to which it is justly entitled.

For over twenty years the writer has been actively engaged in the manufacture of locomotive forgings and during this period has had an opportunity to follow such forgings in service, being therefore somewhat familiar with the troubles encountered in the manufacture of such forgings, and to the varied contributing causes of failure of such parts.

At this time it might be well to review briefly the materials which have been used for locomotive forging parts:—iron axles, crank pins, driving rods, etc., were applied to locomotives up to a few years ago, and a large number of such forgings are still in service. With the advent of the larger locomotive, it was found necessary to use a material with a higher tensile strength. Naturally the engineer went to the use of straight carbon steels. As late as 1907 or 1908 we find that a material was used of approximately the following analysis, as shown by the ladle test:

	Per Cent
Carbon	0.35 to 0.50
Manganese	0.40 to 0.60
Phosphorus	0.05 Max.
Sulphur	0.05 Max.

At that time little attention was given to check analyses, to determine the amount of segregation, nor was there sufficient care being taken to make certain that a sufficient top and bottom discard had been made to insure only sound dense metal, free from segregation. In the heating of the billet for forging little or no attention was given to the rate of application of the heat, time of soaking the billet, nor the temperature to which the billet was heated for the final forging. In those days a forging made under such conditions was placed in service without ever having seen an annealing furnace. Suffice it to say that a material in such a state was not fit for the purpose intended and it is surprising that the failures were not more numerous. An occasional tensile test was made for record purposes but not used as a basis of acceptance or rejection of the forging.

About 1907 it began to be recognized that annealing was necessary in order to refine the crystalline structure of the metal. At that time driving axles were placed into a flange furnace, the flame usually came

into direct contact with the metal. The forging being heated to a cherry red, being allowed to cool in the furnace or in the air. An improvement was seen in the quality of the driving axles and it was not long before the important forgings such as rods, crank pins, piston rods, etc., were likewise annealed.

At about the same time a few alloy steel forgings (nickel and vanadium) were applied, such forgings being annealed only. Some of these vanadium forgings are, I believe, still in service. The analysis of the nickel forgings apparently was not properly balanced with the result that such forgings did not give the best service.

Late in 1909 or early in 1910 a large number of quenched or tempered chromium-vanadium forgings were applied. Results obtained were most disappointing, as a large percentage failed in service. The failures being due largely to internal strains set up in the quenching medium and to thermal ruptures which were, no doubt, present in the forging previous to the heat treating. The defect being developed to a greater degree through the quenching of the steel.

Soon we find a considerable tonnage of quenched and tempered carbon steel being specified, but again the service results were disappointing. A large number of failures being attributed to internal strains, which were set up due to the rapid cooling of the metal.

The above deals with the past. Let us now consider just what is being done to insure a better locomotive forging today and tomorrow. The writer happens to be connected with the American Locomotive Company whose officials recognize the importance of locomotive forgings and the necessity of every precaution being taken to insure a product which will give the best in quality and a forging which will give the consumer real service.

The following is a summary of the methods of manufacture and the care being exercised to insure the highest quality in such forgings:—An investigation is first made to make certain that the producer is in a position to furnish real high quality steel in the ingot or billet form. Due to the large sectional area of the finished forgings the source of supply for such a steel is somewhat limited. The steel maker therefore uses specially designed "hot tops", selects his charging stock and because of the rigid inspection of such ingots and blooms recognizes the importance of quality in this particular product. It is a common occurrence to see a discard of from 40 to 50 per cent being made to meet the exacting requirements.

In addition to the careful surface inspection of the ingot and bloom to make certain there are no defects present, it is the practice to take drillings from each ingot at a point one-half way between the center and the edge and at the dead center to make certain that the steel is within the chemical range specified and is free from "piping" and undue segregation.

In the case of alloy steel blooms, deep etch specimens are taken from two or three billets adjacent to the "top and bottom discard". This

test must show the steel as being reasonably sound, free from internal ruptures and undue segregation. It is the writer's firm belief that the "etch" of a full size cross section gives more information as to the quality of the bloom than any other test with which we are familiar. In passing permit me to say that one manufacturer had the misfortune to lose twenty-three heats due to internal rupture. This condition could have been discovered only through the "etch" test.

In the case of carbon steel blooms, a tensile test is made from a billet adjacent to the top discard as well as from the bottom discard. The minimum physical properties specified being 82,000 pounds per square inch tensile strength, and 15 per cent elongation in 2 inches.

Samples for chemical analysis to represent both the alloy and carbon blooms are taken from two or more "tops" cut billets (adjacent to the top discard) and from two bottom billets. Drillings being taken at the dead center and at a point one-half way between the center and the edge. It is to be noted therefore that these tests insure only the acceptance of real quality billets. All billets being cut to an individual length by a cold saw enables one to detect all evidence of piping.

The heating of the steel for forging is of vital importance. All alloy steel blooms are either preheated or charged into a cold furnace and the heat applied slowly. This is of great importance as heating too rapidly is dangerous and may result in thermal ruptures. A definite schedule has been worked out according to the sectional area to permit a proper heat penetration throughout the entire billet. Oil-fired regenerative furnaces equipped with electric control pyrometers insure complete control over the heating, guards against overheating and isures the proper forging temperature.

All axles and crank pins are forged under a 1000-ton press while the driving rods and other heavy forgings are forged under a 12,000-pound hammer.

Next comes the heat treating department where all the ills of the open-hearth, rolling mill and forging plant are cured. Here we have a large battery of oil-fired furnaces where the forgings are treated, the temperature being controlled by electric pyrometers and checked again by the Siemens' water pyrometer. Care is taken when placing the forgings in the furnace to make certain that the heat can radiate around the entire mass to insure uniform heat penetration. The forgings (both carbon and alloy) being normalized and annealed to meet the most exacting physical and micro requirements. Very few railroads require that the steel be quenched.

After the usual inspection, which includes tensile, chemical and micro tests, the forgings are sent to the machine shops where care is taken to remove tool marks, etc., special attention being given to insure ample fillets with large radii.

There seems to be a difference of opinion today as to the type of steel which will give the best service. Alloy steel is being used by some roads with apparent success. At the same time several railroads have

had results which have been disappointing. The question so often raised being—"Why has the alloy steel not been a success on the railroads while it has in automobile parts?" This can be partially explained, at least, as follows—

(1) That due to the large sectional area in the railroad forging it is necessary to pour very large ingots which might develop thermal ruptures in cooling or heating, which ruptures have likewise developed in the heating or cooling of the blooms or forgings. Little or no trouble in the straight carbon steel has been experienced in this respect.

(2) Only a few of the railroads are equipped with annealing facilities so that no matter what care is exercised by the manufacturer to insure the best in heat treatment, when the railroads are called upon to straighten or repair an alloy steel forging the structure of the metal after being repaired is questionable. For this reason a straight carbon steel of the proper composition seems in the opinion of the writer to have its advantages, especially when it comes to questionable treatment on the part of the users.

Again there is difference of opinion as to whether a high tensile strength is of greater importance than ductility. It is the writer's opinion that we have been wrong in using steels (carbon and alloy) of such high strength, even at the sacrifice of ductility, and I feel that better results would be obtained from a service standpoint were we to use a steel normalized and annealed showing a tensile strength ranging from 76,000 to 85,000 pounds per square inch, with a corresponding high ductility. Experiments which I have recently made in the attempt to learn the effects on the metal of the heating of a locomotive journal, through the lack of lubrication in service, and the rapid cooling through the application of water (which is frequently resorted to) seems to indicate that such a material will resist such service the better. Likewise the effects of tool marks, insufficient fillets, battering and marring in service would be less serious as affecting the life of the forging in this type of steel as compared with a higher strength material, be it alloy or straight carbon steel.

In passing please permit a few direct comments in connection with Mr. Greene's paper. It is to be noted that Mr. Greene in quoting physical properties refers to elastic limit. I presume that the results quoted should really be the "yield point" which is what is actually obtained in most commercial testing.

As regards the size of ingot which would permit a sufficient reduction between ingot and bloom and bloom and forging would say that pressed billets or forgings can be secured which will permit a very large reduction between the ingot and bloom or forging. The question of the amount of reduction, which is actually necessary, is questionable. Our forefathers hand down a legend to us that a reduction of at least four to one in cross sectional area was necessary to produce a desirable billet or a reduction of five to one in cross sectional area when making a forging direct from the ingot. An investigation recently conducted by the writer indi-

cates that equally as good results can be obtained with a reduction as low as three to one. This is of vital importance because of the fact that we all recognize that in the larger ingot there is a greater tendency for segregation.

As regards the variations in physical properties in the quenched S. A. E. 3140 material referred to on page 574 of the paper, it is apparent that the proper time and care was not taken in the heat treatment. Uniform results throughout the section are obtained daily through careful heat treatment. Further, to assist in this respect, it is now the practice to hollow-bore round forgings. The larger the sectional area of the mass, the larger the diameter of the hole.

The question of fatigue failures due to tool marks, fillets with an insufficient radii, with the tool marks not removed, as well as nicks and sharp indentations, are responsible for a large percentage of the failures in high strength forgings, be they alloy or straight carbon steel. Such a condition is frequently the nucleus of a defect which progresses rapidly until failure occurs. The heat checking of a forging due to the lack of lubrication is a serious problem and is likewise responsible for many failures.

The microstructure, Fig. 4, representing a quenched carbon structure does not indicate that the metal had been given a proper heat treatment. This is not a typical structure as better work is done daily. Neither are the physical properties representative of that normally obtained in a quenched carbon steel forging.

Referring to the unetched specimen, Fig. 5, I cannot agree that it is a common occurrence to see a steel containing inclusions equal to this specimen. In all my experience in the study of failed forgings I have never seen a steel so badly contaminated with slag as shown in this specimen. Certainly it is no credit to the steel manufacturer.

As regards the internal ruptures or fissures, would say that the deep etch is of value in locating such defects. Whether or not the slag inclusions are in any way responsible for the internal ruptures is a question as I have seen a large number of quenched ruptured forgings when the steel is sound and unusually free from slag.

Recognizing that the quenching in a quenching medium was too drastic a treatment for the larger sections in both the alloy and carbon steels, the manufacturer and consumer have been inclined to return to the annealed forging. It is the practice today to normalize and anneal both the carbon and alloy steel forgings. The normalizing, of course, enables the manufacturer to obtain better physical properties, especially ductility, and a better grain refinement. Today a few railroads have included in their specifications micro requirements to cover grain size. This requirement can only be met by normalizing. The physical properties quoted by Mr. Greene throughout his paper are very unusual and I am certain that no manufacturer could agree to work to such requirements as rejection limits.

As regards the different types of alloy steels used would say that a

considerable tonnage of chromium-vanadium, carbon-vanadium, nickel and high manganese steels, normalized and annealed, are now in service. At the present time we are experimenting with nickel, manganese, and molybdenum steel forgings in order to learn their possibilities.

I have often seen normalized and annealed forgings with a well-defined ferritic segregation. It must be recognized that the amount of grain refinement possible in the heat treating plant is limited and I have seen forgings which have been overheated to such an extent that it was impossible to break up the ferrite segregation by a normal treatment.

In conclusion, the problems today before the manufacturer and the railroad and which should be given careful consideration briefly summarized are as follows—

1—Is there a necessity for the higher strength forging? If so, can better results be obtained by the use of alloy or straight carbon steel?

2—Is the question of ductility not of vital importance and worthy of serious consideration?

3—Should not a steel be furnished which is as near fool-proof as possible to make which steel will best withstand the abuse to which it is subjected in service?

4—Better machining with proper fillets having ample radii and all surfaces smoothly finished.

5—Should not the question of better lubrication and better maintenance be given more careful thought and attention than it has in the past?

Written Discussion: By Lawford H. Fry, metallurgical engineer, Standard Steel Works Co., Burnham, Pa.

Mr. Greene's paper is very timely in calling attention to the advances which are being made in the use of special normalized carbon steel forgings for locomotive work. The difficulties he quotes as having been encountered with alloy and with quenched carbon steel forgings can be duplicated on many other railroads, and because of these difficulties the use of special normalized carbon steel forgings for locomotive work is increasing. The information Mr. Greene gives is valuable, but two important factors with which he does not deal fully deserve consideration. These are service conditions and the preliminary processes of manufacture of the forgings including the making of the steel itself. In modern railroading with heavy power units and high speeds, locomotive forgings work normally under severe conditions of service, and are subjected occasionally to abnormal abuse. Responsible railroad officials endeavor to have their locomotives handled carefully, but journals run hot occasionally and sometimes an engine man interested in making time will use water to cool down the box. Under such treatment the surface of the journal may be cracked circumferentially and longitudinally, giving an alligator skin appearance which is almost certain to lead to failure if the axle is continued in service. Such treatment is almost immediately fatal to a high tensile alloy steel or to a poorly made carbon steel whether quenched or normalized. The railroads are trying to eliminate excessive abuse, but for driving axles, crank pins, side rods and piston rods hard

service must be counted on and the progressive manufacturer of such forgings aims at producing material which will stand up as far as possible under the most severe conditions.

One of the first requisites in the manufacture of such forgings is well-made steel properly handled in the processes from ingot to billet. Mr. Greene in Fig. 5 shows a photomicrograph of nonmetallic inclusions in steel and says that such conditions are commonly encountered and may be exceeded. Judgment as to inclusions based on photomicrographs is extremely difficult. Much depends on the polish of the specimens and on the field chosen. If, however, the dark spots in Fig. 5 are all actual nonmetallic inclusions and if the field examined, which it must be remembered is only one-fiftieth of an inch by three one-hundredths of an inch, is properly representative of the material generally, the steel cannot be considered as desirable raw material for the manufacture of high grade forgings. To produce satisfactory forgings the maker must have steel reasonably free from inclusions and this must be cast into ingots which are allowed to solidify properly to avoid porosity or a loose central structure. Too large an ingot is not desirable as the slow cooling of large ingots tends to produce secondary segregation.

Many attempts have been made to devise specifications for billets which shall insure good forgings, but the problem is extremely difficult. Steel making is an art and not an exact science, and the forging manufacturer must rely to a great extent on the ability and integrity of the producer of the steel. It is a great advantage when steel making and forging are under one management with undivided responsibility.

As clean deoxidized steel is a necessity, the use of acid open-hearth steel offers appreciable advantages. The able paper presented by Mr. Furness[1] to the Society in 1925 describes clearly the cause of the superiority of acid open-hearth steel. After such steel has been correctly made it is good practice to cast it into properly proportioned ingots which are allowed to cool to at least 750 degrees Fahr. so as to ensure complete solidification before being reheated for further working.

The figures below supplement those in Mr. Greene's paper and show the results obtainable with the steel practice indicated above. The test results given cover the forgings for thirty locomotives and are taken from a report which was being compiled when Mr. Greene's paper come to hand. The steel was made by the acid open-hearth process. After cooling, the ingots were press-forged to billets, the forgings shaped from the billets by steam hammer or press and then normalized and annealed. Sixty tests are covered representing driving axles, crank pins, piston rods and connecting rods, a total of about 660 forgings. The dimensions of the end from which the test specimen was taken were:—Driving axles 10¾ and 11½ inches in diameter, crank pins 5¾ and 8¾ inches in diameter, piston rods 5⅝ inches in diameter, connecting rods 10 inches by 5 inches, 11 inches by 5 inches, and 11 inches by 3 inches. The forgings

[1] "Acid Open-Hearth Steel Melting Practice," by Radclyffe Furness. TRANSACTIONS, American Society for Steel Treating, Vol. 8, 1925, p. 728.

were ordered to specifications calling for the following minimum values of the tensile properties:—

Yield Point	50,000 lbs. per sq. in.
Tensile Strength	85,000 lbs. per sq. in.

	Up to 9 in. diameter or thickness	Over 9 in. diameter or thickness
Elongation in 2 in. per cent	$\frac{2{,}130{,}000}{\text{T. S.}}$	$\frac{2{,}000{,}000}{\text{T. S.}}$
Reduction of Area per cent	$\frac{3{,}400{,}000}{\text{T. S.}}$	$\frac{3{,}200{,}000}{\text{T. S.}}$

The driving axles are over 9 inches in diameter, while the other three classes of forgings are all less than 9 inches in diameter or thickness. The average, minimum and maximum values for the sixty tests are shown in Table I. These tests represent 26 melts of steel of which the compositions range between the following limits:—

	Per Cent
Carbon	0.42 to 0.52
Manganese	0.53 to 0.69
Silicon	0.19 to 0.32
Phosphorus	0.027 to 0.045
Sulphur	0.024 to 0.037

It will be seen that the physical properties are very similar to those given by Mr. Greene in connection with his Fig. 18. If my recognition

Table I

Physical Properties of Locomotive Parts

	Crank Pins, Connecting Rods, Piston Rods Less than 9 In. Dia. or Thickness 43 Tests			Driving Axles Over 9 In. Diameter 17 Tests		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Yield Point, lbs. sq. in.....	54,000	56,000	51,000	54,300	56,000	50,500
Tensile Strength, lbs. sq. in.	90,300	96,000	85,000	90,700	93,500	85,500
Elongation in 2 in. per cent....	25.5	28.0	23.5	24.8	26.5	22.0
Reduction of Area per cent....	43.3	52.0	37.5	40.3	45.0	37.5
QUALITY FACTORS						
Ten. Str. multiplied by Elongation.	2,290,000	2,560,000	2,130,000	2,250,000	2,420,000	2,140,000
Ten. Str. multiplied by Reduction. .	3,900,000	4,260,000	3,230,000	3,660,000	4,000,000	3,240,000

of Fig. 18 is not at fault the resemblance is a family one. The tests are characterized by a high elastic ratio, the yield point averaging 60 per cent of the tensile strength. This is attributable to the use of acid

steel press-forged to billets which gives a clean dense homogeneous structure to the forgings. The attainment of high values for yield point and tensile strength while maintaining adequate ductility is favored by the specification to which the forgings were ordered. This specification differs from that quoted by Mr. Greene in having the elongation and reduction of area requirements based on a sliding scale instead of on flat

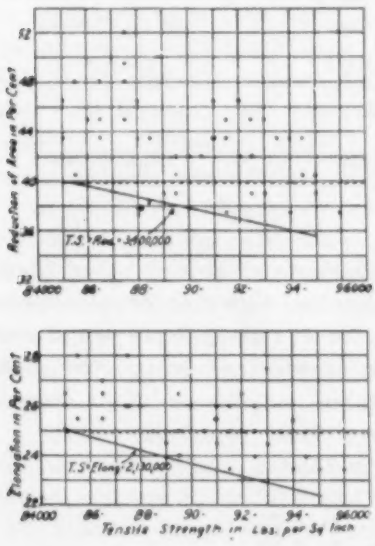

Fig. 1

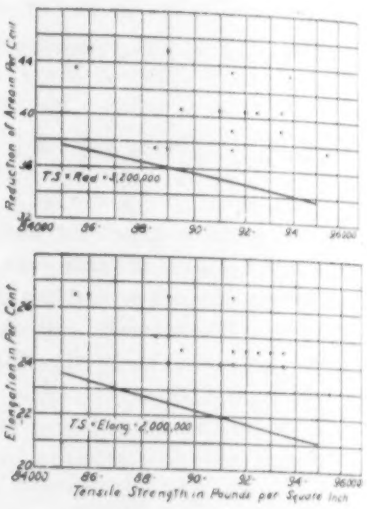
Reduction of Area in Per Cent
T.S. × Red. = 3,200,000
Elongation in Per Cent
T.S. × Elong. = 2,000,000
Tensile Strength in Pounds per Square Inch

Fig. 2

values. The difference between the two types of specifications is illustrated in Figs. 1 and 2 (this discussion) in which the elongation and reduction of area are plotted against the tensile strength. The results of the forgings under 9 inches in diameter or thickness are plotted in Fig. 1, and the results for the driving axles which are over 9 inches in diameter in Fig. 2. In each plot there is a very evident tendency for the ductility values, elongation and reduction of area, to drop as the tensile strength increases. This tendency is of course well known and is allowed for by the use in specifications of so-called "quality factors" obtained by multiplying the elongation and the reduction of area respectively by the tensile strength. With forgings of steel of a given type and quality the unavoidable slight variations in composition, size and treatment produce variations in tensile strength. If the quality is to be the same, these variations should be accompanied by corresponding but opposite variations in the ductility values. Thus forgings of the same quality might have a tensile strength of 85,000 pounds per square inch with an elongation of 27 per cent, a tensile strength of 91,500 pounds per square inch with an elongation of 25 per cent, or a tensile strength of 95,000 pounds per square inch and an elongation of 24 per cent, the quality factor of tensile strength multiplied by elongation being in all three cases 2,290,000. Specifications based on a sliding scale of this sort require increased ductility with lowered tensile strength. If on the other

hand a fixed figure is set for the elongation acceptance is extended to forgings of the lower tensile strengths without a corresponding increase in the ductility being required, and the tendency of the producer will be to aim at the lower tensile strengths as with these the required fixed ductility will be more easily obtained. In the plots of Fig. 1 and 2 curves are drawn corresponding to the minimum ductility requirements determined by the quality factors of the specification. These parallel closely the general tendency of the points plotted and are evidently reasonable and logical minimum values. The horizontal broken lines plotted in the figures represent fixed values for elongation and reduction of area. If these were adopted as rejection limits many of the results plotted would be unacceptable, and to work to such limits it would be necessary for the tensile strength and yield point to be kept down toward the lower limits. Consideration of the subject leads to the belief that the sliding scale for ductility requirements ensures a uniform quality of forgings to the consumer and tends to give a larger proportion of these forgings in the higher tensile range. The use of fixed ductility requirements on the other hand imposes restrictions on the producer without giving the consumer any corresponding advantage.

The A. S. T. M. and A. R. A. specifications for annealed carbon steel forgings provide sliding scales for ductility and it seems to be logical and desirable to follow this established practice when specifications with more severe requirements are adopted. The state of the art has now advanced to a point when such specifications are being widely used and Mr. Greene's paper should be of assistance in showing the advantages to be expected from the adoption of high grade carbon steel forgings.

Written Discussion: By Charles McKnight, The International Nickel Co., New York City.

I think that in the first part of his paper when Mr. Greene compares the nickel and nickel-chromium steels in the heat treated state to other forging steels in the normalized state, he has not given these materials the consideration they deserve and has unintentionally drawn an unfair comparison.

Conclusions are also drawn that the unsatisfactory service of such steels in railroad service was largely due to inadequate ingot size and susceptibility to weakness from cracks originating in tool marks, bad fillets, etc. Mr. Greene will, I believe, readily admit that steels containing nickel are no more subject to such evils than any other alloy steel and, for my part, I will go further to include any and all steels of equal carbon content and with similar heat treatments.

Nickel steel has been increasingly used recently in locomotive construction as a normalizing steel. It is true that we have not been running as high as 3.0 per cent in nickel, due to economic considerations, and that we have not employed chromium at all, but we have, nevertheless, gotten excellent tensile characteristics and, as far as I am able to determine, impact and fatigue results which are as good or better than any others.

My main effort lately has been to harp on the fact that whether it be carbon, vanadium, manganese, chromium, molybdenum or what not, we have about reached the limit in strength which can be expected of a normalized steel, and that we have reached this limit by sacrificing toughness for strength. Personally, I believe that if the locomotive builder and user would be satisfied with a slightly lower yield point and with a very much increased toughness as indicated by the percentage of elongation and reduction of area, together with the impact and fatigue values, we all would be better off. For that reason, we have been advocating the use of a fairly low carbon nickel steel. A typical analysis would run:—

	Per Cent
Carbon	0.20-0.30
Manganese	0.70-1.00
Silicon	0.15-0.30
Phosphorus	Under 0.05
Sulphur	Under 0.05
Nickel	2.00-2.50

With such a steel, given suitable normalizing treatment, we can obtain a yield point in the neighborhood of 60,000 pounds per square inch; tensile strength about 85,000 pounds per square inch; elongation 25-30 per cent and reduction of area of 50-60 per cent with extremely good impact values and a high fatigue ratio. Such a steel is peculiarly suited for use as pins and axles. Under the abuse of overheating and rapid cooling, this low carbon nickel steel shows less tendency to heat-check with its consequent dangers than, I believe, any other steel.

Returning for a moment to the quenched and tempered alloy steels, while I am by no means an advocate of such a treatment for forgings of the size used in locomotives, I was, nevertheless, agreeably surprised in Europe to find that a great many of their reciprocating parts, particularly piston rods, main and side rods and valve motion work, were habitually made of high nickel-chromium steel quenched and tempered and that they reported practically no breakage.

Oral Discussion

H. J. STEIN: Mr. Chairman, we have listened to an excellent paper, that has created quite a bit of discussion on the forging of locomotive parts. Having had more or less to do with railroad forgings at a period three, four or five years ago, I believe that in making main rods and side rods, that particular stress should be laid upon reduction, that is the reduction that is given the steel from the billet to the finished forging. We will all sometimes try to beat the cost by buying billets near to size of forgings, and will give them a minimum amount of work to get them to the finished forging. In doing that, we turn it over to an experienced man in the shop and he gives it a heat excessively high, and with the minimum amount of work

that is necessary to forge the rod into its shape, it does not receive the reduction that it should, because we have gone back to the excessively large crystallization induced by that high temperature of forging. Great stress should be laid on the forging operation.

In Mr. Greene's paper I am questioning only the second paragraph on page 576, in which it says "Fig. 4 shows the structure typical of such quenched and tempered steel. The sample was taken from a driving axle 12 inches in diameter." I do not thing it is right, or good practice, to quench any section above 7 or 7½ or 8 inches in diameter. I think perhaps Mr. Greene forgot to mention this in his paper, but it should be mentioned to make it perfectly clear, so as not to be misleading to men who might not have had the experience. It is necessary in cases like that, in highly reciprocative parts, to hollow-bore and then give the treatment.

M. A. HERZOG: The railroad which I represent does not use quenched and tempered locomotive forgings, for the reasons set forth in Mr. Greene's timely and interesting paper, namely, the danger of failure due to internal stresses which have not been relieved by the tempering process. We have therefore confined ourselves entirely to normalized forgings, mostly of the straight carbon type, with a few carbon-vanadium steel forgings. We therefore agree with Mr. Greene that normalized or annealed forgings have certain advantages over quenched and tempered forgings for locomotive use, but there are one or two statements appearing in Mr. Greene's paper which are contrary to our experience.

In discussing the disadvantages of quenched forgings, Mr. Greene says, "A further effect of the amount and segregation of the nonmetallic inclusions in quenched and tempered material is the ferritic segregation around or near the impurities," and he later makes the statement that well-defined ferritic segregation is seldom found in normalized forgings.

During the past three years we have done a considerable amount of metallographic work on locomotive forgings and have found in many cases a large amount of ferritic banding surrounding nonmetallic inclusions in normalized carbon steel forgings of the composition given in Mr. Greene's paper. Although my experience with quenched forgings has been much more limited, I have found always a much greater percentage of normalized forgings to show well-defined ferritic segregations or banding than was the case with the quenched forgings which we examined. I have with me some photomicrographs illustrating this condition in normalized forgings which I will be glad to show to anyone interested. Since it is generally admitted that ferritic banding in steel is undesirable from the standpoint of resistance to shock and fatigue, and because of a number of failures of locomotive parts that seemed to be traceable to such structures, we are now purchasing our important locomotive forgings to metallographic specifications, in addition to the usual physical and chemical tests. These specifications require the steel to be substantially free from banding, in addition to limiting grain size, and, as far as practical, limiting nonmetallic inclusions. And, in parenthesis, I would say that I agree entirely with Mr. Edwards and Mr. Fry that the author's Fig. 5 represents a degree of segregation or number of inclusions

that is very abnormal for locomotive forging steels, and we would have no hesitation whatever in rejecting finally and without recourse any forgings showing such a condition.

Our specification has aroused considerable opposition among those producing locomotive forgings, as they claim that they cannot consistently control banding in steel. We have, however, insisted, and are now receiving forgings in which well-defined banding is absent and in which grain refinement and relative freedom from nonmetallic inclusions is satisfactory. We are, of course, paying somewhat higher prices for such steel, but we feel that it is money well spent.

Because of the controversy that seems to exist among steel men as to the harmfulness or innocuousness of ferrite banding, I would like very much to hear some discussion on the subject as to whether we are justified in our insistence on freedom from banding in our forgings from the standpoint of current steel-making practice.

L. F. REID: Mr. Chairman, I am not a member of this organization, but I was sent here by one of the greatest railroads there is in the United States to learn something about steel treatment, and I want to tell you that I would not take anything for the information that I have gained here at these meetings.

Now, in the last three years on the railroad that I represent there has been something like six thousand side and main rods manufactured. All of them are carbon-vanadium steel, and if there has been three failures on the entire road in the last four years, I have never heard of them. Each month I would assume, in Little Rock and Sedalia, there have been 200 rods made for the last 18 months, each month. Those rods are machined all over. The forging of a rod, gentlemen, is where you get the good results, in my judgment. We try to heat to 2100 degrees Fahr. and never to forge to below 1650 degrees Fahr. Now, whether that is right or wrong, I do not know, that is what I am here to find out. We hold them in a normalizing furnace for about 18 to 20 hours. We pull them out and let them cool, in ordinary practice, to below 1000 degrees Fahr., then put them back in the furnace and carry them to 1300 degrees Fahr. and hold them for five or six hours and then let them cool in the furnace, and those results have been shown, which would seem to indicate that the practice must be good, although it is being handled by men who know little about it. Personally I know little about heat treatment, because my work is on the forging end. I have been intimately connected with railroad forging for the last 22 years, as foreman of the North Little Rock Shops. The Missouri Pacific railroad employed a gentleman, a heat treater, a few years ago and he has taught us a great deal about it, and if every railroad in the country would adopt the policy that the Missouri Pacific has, I believe we would eliminate failures, absolutely.

J. S. VANICK: There seems to be an astounding difference in the tone of the paper presented by Mr. Greene and the discussion by Mr. Edwards, where I think in Mr. Edward's discussion, the keynote of the problem is sounded in getting lower tensile and more ductility for the peculiar requirements of

railroad steels. It seems to be necessary to satisfy their particular requirements with higher ductility in order to meet the simple anneal treatments which they can apply until they can elevate their practice to properly treat the higher tensile alloy steels and perhaps train their shops and crews to a proper realization of, and respect for, the importance of a proper treatment of the higher strength alloy steels.

The failures described here as being service failures are all of alloy steels of the rather high carbon type. To meet the requirement for lower strength and more ductility, nickel steels, (for instance, of the S. A. E. 2320 type,) are being produced, which are lower in carbon, and which improve the ductility, perhaps at some sacrifice of strength, but meet the heat treatment conditions which are imposed, retain the toughness necessary for service, and add considerably to the fatigue life of forging steels of this type.

R. S. MACPHERRAN: There were one or two references to the question of banded ferrite and its first cousin, ghost lines. It has seemed to me that this is a topic that this society might very well take up to determine the relative or the quantitative effect of ghost lines. The matter is always coming up in the shop, we are all receiving, more or less, forgings in which ghost lines or banded ferrite occurs, and it has seemed to me to be a very good subject for someone to develop in the way of a paper for the next or some subsequent convention.

Author's Closure

O. V. GREENE: I rather heartily agree with all the people who discussed the paper in connection with the lowering of the ultimate strength and increasing the ductility. I do not think there is any question about that for producing better results and fatigue limits than the average quenched and tempered material which the shops have been using.

In reply to Mr. Edwards, who asked about the elastic limit, I will say that the elastic limit of all the tests, with the exception of those at the end, of normalized carbon steel, were taken with an extensometer, while those of normalized carbon steel were taken by the "drop of beam."

Mr. Edwards also spoke about the nickel-chromium steel, and I will agree with him that the heat treatment of the nickel-chromium steel was extremely poor. Also, he mentioned the results of quenching large forgings. Our specification requires that large forgings, particularly axles and rounds, should have a hole at least 20 per cent of the diameter. Consequently the wall thickness is seldom greater than five inches.

In Fig. 5, of which considerable mention has been made with reference to the nonmetallic inclusions, that particular axle had failed in service. It was bought from a forging manufacturer (and not made by the railroad company.) As it happened, it was not the test axle. That is, we accept one test for a number on a certain heat and the axle that failed might have been near the top of the ingot, or anywhere,—we have no record of its heat treatment, and no record, of course, of the test of the axle in its original state.

Mr. Edwards also mentioned the size of the ingots. This is a big consideration when you think of a main rod. Not long ago we converted a

Mallet-type locomotive to a Santa Fe and the side and main rods were extremely large, the main rod had a bearing end possibly 23 inches wide as finished. If you take a billet that is made from an ingot large enough to do that, you can see that one side has had practically no work at all, and if an ingot has been extremely large, naturally, we have not broken down the ingotism which might be there, or anything else, except as you can do in the treatment.

Mr. Fry also mentioned about the sliding scale idea for accepting forgings, and, of course, that is what we use. I merely mentioned the specification in the paper on which smaller forgings, such as crank pins and piston rods, can be bought if you pay the price. However, a great many people are using the A. S. T. M. specifications A20-21 entirely.

One of the last speakers remarked about quenching very large axles. I heartily agree that nothing over six or seven inches should be quenched, whether it has been hollow-bored or not. His remarks were very pertinent.

Mr. Herzog in his discussion states that he has found ferritic segregation in normalized forgings. I did not mean to convey the impression that simply because a steel was normalized only, it would not show ferritic banding. There is even an instance of this in normalized steel in the paper. Figs. 10 and 16 of manganese steel show a segregation of ferrite even in the cross section. My intention was to convey the fact that normalized steels seldom contain a ferrite segregation that will be sufficient to cause a non-uniform structure in the cross section. Incidentally it is claimed that ferritic segregation in the longitudinal section unless it is very bad, can be appreciably reduced or entirely eliminated by a correct heat treatment followed by the ordinary normalizing treatment.

ON THE THEORY OF HEAT

(Continued from Page 572)

in lime kilns and blast furnaces. The combustion is much more active against the wall. The hot zone then assumes the shape of an ellipsoid. The length of the long axis of this ellipsoid may even exceed the height of the furnace. In the same horizontal cross section we may further find all the zones in close contiguity, and on account of their proximity drops in heat occur between them which tend to make the temperature in the furnace homogeneous. If this homogeneousness were complete, the shaft furnace would lose all its advantages and would not give a greater efficiency than that of the reverberatory furnace.

This cause of disturbance is too irregular to be calculated. It is the source of all the difficulties encountered in the operation of shaft furnaces. Its importance is of the same order of magnitude as that of the results of the laws of energetics.

DEVELOPMENT OF HIGH SPEED STEEL HACK SAWS OR CUTTING OFF SAWS

By Henry B. Allen

Abstract

This paper discusses the application of high speed steel to machine hack saw blades. A description of the hardening process brings out some interesting properties of high speed steel not usually apparent when dealing with the customary heavier sections. The steel is shown to be plastic for some time after hardening, even when it is above a hardness of 62-C Rockwell. Neither does it attain full hardness for a considerable time after becoming quite cold. The relative performance of saws made of high speed steel and low tungsten steel is also shown.

THE greatest return per dollar spent is the fundamental principle guiding present day manufacturing. The machine or tool which will produce the most for the least investment and operating cost is usually the one used. Thus high speed steel revolutionized machining operations.

It is true that high speed steel itself is several times more costly than its predecessors, and its manufacture into tools is more costly. But the service resulting from its use is so vastly greater than that which could be had previously that its adoption has become almost universal for production work. A large proportion of all metal used as a raw material for manufacture has, at some stage, to be cut off into convenient sizes or shapes. It is this operation where the metal saw has its principal use. While there are many different types of metal saws, in the final analysis, they all fall within one of the following classes:

1. Friction disks
2. Fast running circular saws
3. Slow running circular or milling saws
4. Band hack saws
5. Reciprocating hack saws.

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. The author, H. B. Allen, a member of the society, is associated with the Henry Disston and Sons Co., Philadelphia. Manuscript received July 19, 1927.

The Friction Disk, which may have a smooth or a nicked edge, operates, as its name implies by friction. It literally melts its way through the piece being cut. In order that enough heat be generated the disk is run at tremendous speeds, up to a rim speed of 4 miles or more per minute. It is used principally for cutting structural and tonnage steel to length, or, in general, where a smooth cut is not essential and where the heat developed will not set up air hardening checks in the work.

The Fast Running Circular Saw is a toothed blade operated at rates up to about 15,000 feet per minute rim speed. In some cases it operates partly by friction, as does the friction disk, but often by pure cutting as when used on thin sections of softer nonferrous materials.

The Slow Running Circular or Milling Saw, as its name implies, is operated according to usual machine shop practice and cuts in the same fashion as does a milling cutter. The teeth may be integral with the blade or may be removable. This type of saw may be used wherever an accurate, clean cut is required.

The Band Hack Saw is a narrow, thin continuous strip, with teeth along one edge. It finds application for general cutting off operations, and, except for thin sheet and nonferrous metals, runs at more or less conventional metal cutting speeds.

The Reciprocating Hack Saw is so generally familiar to those whose interests bring them in touch with metals that little need be said about the way it operates. In the past it has been largely used for miscellaneous cutting off work, generally of a nonproductive nature.

Each of the above types of saw occupies a field to which it has been found by experience best suited, both by character of cut and cost. It may be said that the practice of sawing metals has become, to a great extent, stabilized. But as in all lines of endeavor when a new development appears there is an unbalance set up. We then have to review the entire situation to see where the new development can be applied to make the dollar earn still more. Such a situation existed upon the introduction of modern high speed steel and such has arisen today in the more limited field of saws for metal cutting.

It is difficult to name any new commercial development, large or small, which has not been antedated by an idea of someone who

long before has had the vision to see the future possibilities and anticipated applications. Shortly after high speed steel appeared we find reference to the feasibility of its usage in that manner which is the subject matter of this paper. Only a few years ago, such a development appeared on the market. But as is apt to be the case, some factor, either cost or otherwise, prevented its wide use until now.

An interesting fact in the history of metal cutting is that the direct survivor of the oldest metal cutting tool known to man, the hack saw, is the latest one to be made out of that master tool steel of the age, high speed steel. The lathe tool, the drill, the milling cutter, the circular saw, all of which form the foundation upon which modern mechanical production is based, have made possible our progress during the past 30 years by reason of adoption of high speed steel in their manufacture. The hack saw, on the other hand, until today was at the same stage in its development that these other tools were when the high speed steel first made its appearance.

Plain carbon tool steel during the last century was used for hack saws as it was for other tools; the only distinction being that the carbon content was apt to be made very high, (in the neighborhood of 1.20 per cent or higher) or up to the point where the blade became too brittle. The real reason why such a high carbon steel made the best hack saw was made apparent upon the introduction of the microscope for the study of steel, at which time the effect of the nature and distribution of hard carbides become known.

Following the introduction of low tungsten tool steels they were found to be admirably suited for hack saws and were largely adopted. Here again the carbon content was often made high, taking advantage of the very hard carbide particles resulting therefrom. Today, except for the high speed steel blades now being introduced, the large majority of hack saws are made of such steels.

Mention should be made of a saw lately introduced, made of a very high (around 12 per cent) chromium steel with high carbon and some molybdenum and cobalt. In light of the remarks made above concerning carbides the application of this steel is interesting as it is literally packed with carbide particles. As might be expected, a cutting tool made of it will last longer than one made of the usual steel.

Why is it that high speed steel is only at this late date being commercially used for hack saw blades? The mechanically operated or machine hack saw is in its field a very economical tool. Its use is steadily increasing. Statistics[1] show 652 hack saw machines produced in 1923 and 1499 in 1925. The hack saw blade is the simplest form of saw; merely a strip of steel with teeth along the edge. The answer to the question asked at the start of this paragraph is a paradox; the very simplicity of the saw has until now made the application of high speed steel to it commercially not possible. The consumer has in the past considered the hack saw blade, as also the file, merely a tool for which he pays a few cents, uses, or misuses, until dull and then throws away. This habit of mind has made commercial application of high speed steel to hack saws impossible until the makers could produce them at a sufficiently low cost as well as make a tool that would cut much better. The hack saw machine builder has also played his part by producing a machine which now ranks in a place among modern production machine tools.

Let us briefly trace the development of high speed steel heat treatment. As a result of Taylor and White's discovery of how to heat treat the forerunner of our modern high speed steel to bring out its useful properties, entirely, new technique and equipment had to be developed.

Even at that day when the use of carbon tool steels was centuries old and simple alloy steels had been made into tools for years, the equipment available for their exact heat treatment was, as we know it today, almost nonexistent. Consequently the first applications to which high speed steel was put were of the simplest, such as lathe and planer tools. Their heat treatment was comparatively easy. The nose of the tool had merely to be brought up to a bubbling heat and quenched. A forge fire was all that was needed. The blistered skin could then be entirely removed by grinding down to normal metal.

Tools more difficult to heat treat could not be made of high speed steel until better hardening equipment was devised. Such progress was made and soon more delicate tools such as milling cutters and twist drills were produced. Not nearly so much blistering and burning on the surface could be tolerated from harden-

[1]Private communication with *Iron Age*.

ing, still the cutting edges could be afterwards ground. At this same time high speed steel circular saws, which fall in the same category, made their appearance.

Perhaps the next stage in the development of high speed cutting tools might be considered to cover such tools as taps and dies which could not, at that time at least, be ground after heat treatment. Their requirement meant a hardening method which would in no way alter the previously finished cutting edge of the tool.

The next advance, which brings us up to the present time, covers the machine hack saw blade. This tool, which is commonly made in sizes of from 12 to 24 inches long, 1 to 1½ inches wide, 0.049 to 0.065 inches thick and with from 6 to 14 teeth per inch along one edge, is not ground in any way before or after heat treatment. Its shape is such that in hardening as much consideration must be given to straightness as to proper hardness and toughness.

The blades in question are made from blanks sheared from annealed hot-rolled high speed steel sheet. A typical steel composition used is:

	Per Cent
Carbon	0.65
Chromium	3.80
Tungsten	18.5
Vanadium	1.0

Inasmuch as the final cutting points of the saw are formed in the original surface of the sheet as it comes from the steel mill, the sheet must have a good surface. For the same reason even a trace of soft bark or skin cannot be tolerated. This entails the best mill and annealing practice.

The sheared blanks are clamped on a long milling machine bed and the teeth milled, after which the ends are trimmed to shape and holes punched. The blades next go to setting machines which bend the teeth over for about 0.008 to 0.010 inch, thus giving the saw the necessary side clearance. It is interesting to note in this connection that the teeth are set over a little further than is desired in the finished saw, the reason being that the teeth tend to return to their original unbent position when heated to the high hardening heat. The amount of final set plays an important part in the performance of the saw.

The blades then go to be heat treated. To insure uniformity

the blades are hardened separately. By this method they come up to heat quickly, lessening the danger of overheating the teeth while waiting for the back to reach temperature. While the operation is not critically sensitive, the temperature must be under accurate control to within 25 degrees Fahr. and the time at high heat to within 5 seconds.

For hardening, the blades are hung, through the hole in one end, on a spider made of heat resisting alloy rod. From 6 to 12 blades constitute one batch and are so mounted that each blade receives the heat at nearly the same rate and is not blanketed by another. The preheating is done in a vertical cylindrical gas furnace using no muffle. A loaded spider is lowered into the furnace and held until thoroughly soaked out. A temperature of 1700 to 1750 degrees Fahr. is used. It is needless to say that the proper furnace atmosphere is maintained.

The high heat furnace is also a vertical gas furnace, but in this case it is equipped with a muffle. Proper furnace and burner design insures uniformity of temperature from top to bottom during operation. Uniformity of temperature in the work is important not only for the cutting teeth but also to prevent distortion of blades in quenching. After a preheated batch of blades is lowered into the high heat they require from 1 to 1½ minutes, depending upon thickness, for proper heating. A temperature of from 2325 to 2350 degrees Fahr. is used. Despite the fact that some brands of full high speed steel can be hardened at below 2300 degrees Fahr. so as to show after tempering a high hardness, the writer's experience has been that better performing tools result when such steels are all put through the higher range of temperatures. And such can today be done commercially without injuring the most delicate tools.

After soaking at high heat the charge is withdrawn and quenched in oil. The oil is kept hot, at about 300 degrees Fahr., and the blades are lowered vertically and slowly into it. If the oil is too cool, warpage occurs as it does also if the speed of quench is too rapid. If the blade is quenched out of vertical in the way that the tooth edge enters the oil ahead of the back, the blade will be warped so that the tooth edge is concave, and vice-versa. By quenching vertically the blade will come out as straight as it was prior to heating except for some tendency of some blades to bow.

This condition is to some extent beyond the power of the hardener to prevent. It may be tied up in the past history of that particular sheet or strip of steel from which the blade came. It seems to be true in general of fine-grained steels and of the sluggish high speed in particular that any exceptional strains put in the piece,

Table I

Hardness and Ductility of High Speed Steel Saws at Various Time Intervals after Leaving Quenching Oil

Size—14 x 1 x 0.065-inch

Time after Leaving Quench (Minutes)	Temperature of Steel-Approx. Deg. Fahr.	Hardness Rockwell C-Scale	Permanent Set 2½" Bend	Permanent Set 3" Bend
1½	175	53-57		¾"
5	120	60-62		5/8"
10	70	63		5/8"
15	70	63-64		7/16"
25	70	64		¼"
60	70	64-65	Not broken	Broke
120	70	64-65	Not broken	Broke
180	70	64-65	Not broken	Broke
1080	70	65	Not broken	Broke

Temperature of preheat—1700°F.
Temperature of high heat—2350°F.
Time in high heat—1 min. 30 sec.
Temperature of quench—290°F.

even as far back as hot rolling, will persist and appear in the form of distortion or strain after the piece has been through the high hardening heat. This is the same principle of behavior mentioned in connection with giving the teeth a little extra set to allow for a slight straightening up in hardening.

Before the blades are cooled to the temperature of the quenching oil, they are removed and taken off the spider. After the excess oil has been removed and while they are still somewhat warm they are inspected individually and any that are warped are hand straightened by a simple bending. A blade at this stage is quite pliable and remains so, though to a lesser extent, for some minutes after it has reached room temperature. The figures given in Table I compiled from test data, shows the relationship between hardness and pliability. The test for permanent set consisted of springing the blade into a bow, having either a 2½ or 3 inch chord, by a pressure in line with the axis of the blade. After releasing the pressure the permanent set was recorded by measuring the chord

of the bow which remained in the blade. Between a half and one hour after quenching is the average time before the steel takes on its full hardness. A longer time is usually required for the steel to lose its pliability entirely.

This stage of pliability shown by hardened high speed steel is, of course, of considerable practical value and is made use of in the manufacture of other lines of products. It also points out the

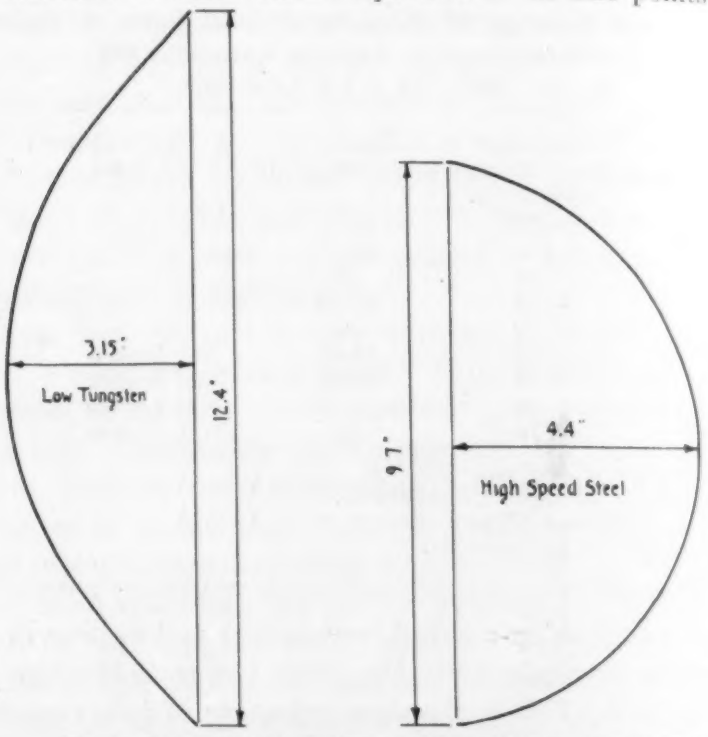

Fig. 1—Comparison of Toughness Between Old Type Low Tungsten Blade and New Type High Speed Steel Blade.

danger, especially where accurate research work is being done, of using hardness readings taken soon after hardening.

As the saws are inspected after hardening, and straightened when needed, they are put under moderate pressure in a clamp. This allows them to cool evenly in a straight condition. When a furnace load of jigs are ready they are charged into an electric tempering furnace where they remain for a 30-minute soak at 1050 degrees Fahr. Tempering, even under considerable pressure, has little, if any, straightening effect on bent high speed steel blades. With carbon or low tungsten tool steels, on the other hand, the amount of straightening that can be done by tempering, even at 400 degrees Fahr., under pressure is remarkable. It is essential in

all cases that the pressure be on while the steel is coming up to tempering heat.

After heat treatment the ends of the blades are semi-annealed around the clamping holes. This is to give that part of the blade by which it is held in the machine sufficient ductility to stand the strains of service. They are next given a very light sand blasting to clean off any light scale from the sides and are inspected for hardness and mechanical quality, hammer flattened where needed, oiled and packed.

Many people, even among those working with tools, think of high speed steel as being inherently brittle. It is usually a source of wonder to those people when they are shown a fully hard high speed tool thrown down upon a cement floor without breaking. A carbon steel tool of the same hardness throughout would shatter. The same distinction is true between a tungsten and a high speed steel hack saw. Fig. 1 illustrates the comparative toughness by showing each blade bent to its maximum amount before breaking.

Much could be said about the mechanical features of the high speed steel hack saw blade, as this phase of the subject is of great interest. The best tooth angles, clearances, spacing of teeth, hardness of the material being cut and at what speeds and feeds; all of these points are equally as interesting as the manufacture. To give a general idea of the relative performance of a high speed steel versus a tungsten steel blade some data from cutting tests are given in Tables II and III.

It is unfortunate that the old original name hack saw which implies a crude saw for hacking through something hard still persists. The saw has now taken its place with the other modern machine tools and it is hoped that some one will suggest a more appropriate name for it. Possibly the name *Cutting-Off Saw* would be appropriate.

While this paper has only discussed the so-called machine hack saws, there are other types, the most important ones being the hand hack saw familiar to all garages and many homes, and the band hack saw. Hand operated tools are slowly but surely being replaced by mechanical operation. The band saw is power driven and is largely used. Whether or not high speed steel has a possible application here also has not yet been fully determined, but if so, it will be used.

Table II

Comparative Performance Cutting Unannealed Tool Steel
Regular Low Tungsten vs. High Speed Steel Machine Hack Saws
14" x 1" x 16 Gage x 10T.

Material Cut: 0.90 per cent carbon, 0.70 per cent manganese, open-hearth steel unannealed billets 4" x 4" square with scale on—Brinell number 247 to 228
Peerless Universal Shaping Saw Machine was used.

Type of Saw	Speed, R. P. M.	Number of Cuts	Average Time Per Cut, Minutes	Square Inches Per Hour	Time of First Cutting, Minutes	Time of Last Cutting, Minutes	Remarks
Low Tungsten Blade.....	89	5	25	35.4	18	33	Completely worn
High Speed Steel Blade....	130	45	12.5	75.8	12.1	19	Completely worn

Table III

Comparative Performance Cutting Machinery Steel
Regular Low Tungsten vs. High Speed Steel Machine Hack Saws
14" x 1" x 16 Gage x 8T.

Material Cut: 0.35-0.45 per cent carbon steel 5-inch Rd.—Brinell number 137.
Peerless Universal Shaping Saw Machine was used.

Type of Saw	Speed, R. P. M.	Number of Cuts	Average Time Per Cut, Minutes	Square Inches Per Hour	Time of First Cutting, Minutes	Time of Last Cutting, Minutes	Remarks
Low Tungsten Blade ...	89	45	21.5	54.7	17.00	29	Completely worn
High Speed Steel Blade..	130	105	10.2	115.0	10.00	11.00	Very slightly worn

(Test discontinued; blade still in good cutting condition)

It is not the writer's intention to claim anything said here in connection with the manufacture of the tool in question discloses new matter about high speed steel. Many of you have undoubtedly carried out equally, if not more difficult, heat treatment operations. Most of you are without doubt familiar with the properties of high speed steel, such as have been illustrated in the manufacture under discussion. Theories to explain these properties have

been published and are constantly being tested. But it is the writer's hope that this discussion has been of some interest as illustrating one commercial application of a new use for the most remarkable of all present day tool steels; and as worked out by applied metallurgy, a branch of which after all is modern heat treatment.

The writer takes this opportunity to thank Henry Disston & Sons, Inc., for their permission to publish the information given, and George Satterthwaite, vice-president, for his helpful suggestions; also members of the writer's staff who have aided in collecting the data.

DISCUSSION

Written Discussion: By H. M. German, metallurgist, Universal Steel Co., Bridgeville, Pa.

The high speed hack saw has a distinct field in cutting very hard and tough steels and such alloys that are almost impossible to cut with the standard low-tungsten hack saw. This field is limited. An estimate of the four largest manufacturers of hack saws in this country shows that approximately 60 per cent of all power hack saws are used in sawing soft and machine steel, 20 per cent in sawing annealed tool steel and the balance for miscellaneous purposes. The adoption of the high speed hack saw has not become almost universal for production work. This statement is backed by the records of the compnay with which the writer is associated and which supplies a very large percentage of all the hack saw sheet steel used in this country. The fact that high speed saws have not come into more general use may be attributed to the following causes, namely, the increased cost of the saws with the accompanying great loss when saws are broken before the saws are worn out, and the cost per cut.

A hack saw is an unground brittle tool that is possibly more abused than any other metal cutting tool. Consider a common size of power hack saw—12 inches long, by ¾ inch wide by 0.049 inch in thickness that has a Rockwell hardness of 61 to 65 C. This blade is operated under a heavy tension, usually limited by the strength of the operator's wrist, at a speed of 50 to 150 strokes per minute, and under a pressure of 60 to 160 pounds. Manufacturers recommend a given speed, pressure, design of teeth, number of teeth per inch for cutting different classes of material, but the advice is not always followed and increased breakage is the inevitable result. Under ideal conditions where the speed, pressure, and tension are accurately controlled, a surprising number of saws break before they are worn out. In a recent test covering four different makes of high speed hack saws, approximately one-third of the saws broke before they were worn out. In several instances the saws broke at the eye during the first cut due to the ends not having been tempered properly.

The loss of a standard 12-inch power saw blade means only ten cents, while the loss of a high speed blade of the same size is sixty-five cents.

It is not possible to get the full benefit of high speed steel in hack saws as obtained in a lathe tool, as the latter is operated under increased speed and pressure to take advantage of its property of red hardness, whereas nothing approximating red heat is obtained in the operation of a hack saw. The present hack saw machine is limited to approximately 150 strokes per minute and the pressure to be within the safe working limit of the saw should be under 160 pounds. The increased cutting ability of a high speed hack saw cannot therefore be attributed to its property of red hardness, but it is due to the presence of hard, stable nodules of free carbides which not only resist abrasion but present a number of very fine cutting points, thereby protecting the cutting edges and enabling the saw to cut longer. By a suitable heat treatment of a modification[1] of the low tungsten hack saw steel it is possible to produce a finished saw containing these free carbide nodules that will show a substantial increase in endurance and speed over the standard low-tungsten saw.

In the present age of economy, the cost per cut is the predominant factor in the adoption of any cutting tool. The cost should include not only the cost of blade per cut, but also labor, output per machine and maintenance per machine. Results should not be based on a few saws, but rather on the average of a reasonable number of saws. It is impossible to draw any cost conclusion from the two tests as shown by Mr. Allen in Tables II and III for the following reasons. First—The pressure in the tests are not shown. Second—The kind of lubricant, if any, is not stated. Third—The speed in revolutions per minute of the low tungsten blade is too fast for cutting unannealed tool steel and is too slow for cutting machinery steel. A committee composed of members of the four largest hack saw makers and one hack saw steel manufacturer, appointed to recommend the most efficient operating conditions for low tungsten hack saw blades after a series of preliminary tests specified for cutting unannealed tool steel a speed of 60 revolutions per minute and 75 pounds pressure, and for machine steel a speed of 138 revolutions per minute and 75 pounds pressure. Fourth—The results of only two tests are shown and one was not complete.

A brief summary of the results from a number of comparative tests show that in endurance the high speed saw is from three to five times greater than the standard low tungsten blade, in tests that the saws were run until they were completely worn; the ratio being greater in very hard material than in soft material. This difference in endurance is less than the above amount of tests in which the saws break prematurely in operation are included. In time of cutting, the ratio varies according to the pressure on the saws, the hardness and the microscopic structure of metal being cut. The only way to compare the cost per cut between high speed saws and low tungsten saws on any particular metal is to make an

[1]This modification and treatment is covered by U. S. Patent No. 1,616,364, assigned to the Universal Steel Co.

actual service test, using a large number of saws, operating each kind under conditions that will give their most efficient results, and keeping a complete cost on all operating conditions. Some users have tried high speed saws and found them to be cheaper than low tungsten saws in cost per cut, while others have found them to be more costly. Judging by the amount of low tungsten steel that is being used for power blades, there is no indication that the adoption of high speed hack saws has become almost universal for production work.

The increase in Rockwell C hardness, as shown in Table I, between readings taken after quenching when the saws have reached room temperature and readings taken several hours later is due to the metallographic structure attaining equilibrium and is termed aging. This is also true of low tungsten hack saw steel and of those steels that acquire an austenitic-martensitic structure in quenching.

Band hack saws were used in England during the War period for cutting off saws. In their manufacture, the bands were toothed and set in the usual manner. In hardening, each tooth was hardened individually by friction heat generated by the pressure of a close-grained emery wheel against the point of the saw tooth. When the saw become dull the grinding and hardening operation was repeated until the saw had lost its set. The teeth were then sheared off, retoothed, set and hardened. The retoothing operation was continued until the band become too narrow for use.

Mr. Allen is to be complimented for the clear presentation of the manufacturing operations in the making of a high speed hack saw.

Oral Discussion

C. T. PATTERSON: I would like to ask Mr. Allen about cutting the high chromium steels that are rapidly coming into use. They are very tough and hard to cut. I have seen many hack saw blades whose teeth would wear right off. I have an idea that the points of those teeth must get pretty hot. I would like to know what you think about cutting those very tough steels.

H. B. ALLEN: Our experience has been in cutting steels of that character that the blade made out of high speed steel would in many cases cut where an ordinary blade would absolutely fail. One case I have particularly in mind is cutting Nichrome, in billets say four inches square. The manufacturer was struggling along with regular low tungsten blades and using, as I remember, about two blades per cut. He tried some blades of high speed steel, which he is now using, and gets, I think, twenty four cuts before the blade dulls. Nichrome is pretty tough stuff to cut. We have had the same experience cutting the kind of steel you mention; I suppose you mean the 12 per cent chromium steel, high carbon.

C. T. PATTERSON: Not necessarily high carbon; all of those chromium steels, from 12 to 30 per cent chromium, with or without nickel.

H. B. ALLEN: The difference in performance of the high speed blade over the regular blade is the same as the difference in performance of high

speed steel in a milling cutter, for example, over what a carbon or a low tungsten cutter would do.

CHAIRMAN J. A. MATHEWS: I believe it is too early yet to know what the final outcome will be on high speed hack saws. Some of us have been in the business long enough to remember how the proportion with regard to carbon twist drills vs. high speed twist drills changed and also between carbon cutters and high speed cutters, and we will have to watch the same process go along for a few years with hack saws before we know what the final outcome will be.

Author's Reply to H. M. German's Discussion

Among the interesting points raised by Mr. German in his remark that high speed steel machine hack saws have not been almost universally adopted in place of the older variety, and also that their field is limited. Actually they have been so recently introduced, only to any extent in the last year or two, and their use is increasing so rapidly that no one can say today what will be the final extent of their application. While it is quite true that the high speed steel hack saw will cut material successfully of a hardness that the old low tungsten blade will fail on, our records show that only a small percentage of high speed blades made are used for such work. The majority are being used for cutting not only annealed tool steel but structural steel, pipe and machinery steel. Undoubtedly the profitable use of high speed blades for such work is aided by the better present day design of machines for operating them.

The statement that the hack saw is a brittle tool really applies more to the low tungsten variety. Due to its thinness, an all-hard hack saw, as distinguished from the type hard on tooth edge only, is of equal hardness throughout its cross section. In other words, it cannot be made having a softer, tougher core, no matter what kind of steel is used, as can a chunky tool made out of shallow hardening steel. But it is well recognized that properly hardened high speed steel is considerably tougher than most other types, particularly the low tungsten high carbon variety such as goes into the old type hack saw. Experience is showing that the amount of breakage in high speed blades is remarkably low even though operating at increased speeds and feeds commensurate with a high speed steel tool practice and some under adverse machine conditions.

Mr. German says that the full benefit of high speed steel in hack saws cannot be obtained as with a lathe tool, as the latter is operated under increased speed and pressure to take advantage of its red hardness property whereas nothing approximating red heat is obtained in the operation of a hack saw. In the first place the manner in which a hack saw cuts is quite different from that of a lathe tool. The cutting point of the latter is continuously buried in the work and cuts through the medium of a false edge built up on the tool nose. A hack saw on the other hand, cuts in much the same fashion as does a milling cutter, and we know that through improvement in steel and heat treatment and also the design of milling machines the use of high speed steel

(Continued on Page 637)

PATENTING OF STEEL

By J. S. Glen Primrose

Abstract

The mechanism and purpose of the special form of heat treatment known as "patenting" is explained, and the different forms of furnaces and heating used are described in detail, from the coal-fired "bee-hive" to the surface combustion continuous form. The different classes of steel commonly treated for particular purposes are described, and the general practice and methods of overcoming faults are discussed from the point of view of physical properties and the accompanying microstructure. Micrographical details are included of the numerous wire specimens examined to ascertain the best methods of control to ensure satisfactory production of the highest quality of finished wire.

THE heat treatment of steel in the form of rods or wire by the so-called "patented" process is a commercial application of a somewhat unusual method whereby an almost overheated structure is imparted to the metal with beneficial results. If it were truly overheated, the result would be a dangerous brittleness, causing the material to break up into short lengths either in the coiling process, or in the subsequent acid cleaning tanks. This effect is seldom accomplished, except under bad management, but the valuable physical property imparted by proper "patenting" is that of enabling the rod or wire to be drawn down to a much finer diameter without any intermediate annealing, and to enable the final product to attain a much higher tensile strength, and toughness under torsion test, than would be possible without the aid of this heat treatment process.

The mechanism of the process consists in raising the temperature of the metal steadily to a range, depending upon the diameter of wire concerned, well above the critical point of the steel involved, secondly the maintenance of this temperature for a period neces-

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sary to allow of complete diffusion of the carbon content, and the growth of the crystal grain size to the maximum allowable for the sectional area, and then this is followed by a sufficiently rapid rate of cooling to bring about the retention of the dispersed carbide in the state of maximum sorbite. It will readily be seen that to achieve this purpose consistently with a number of wires simultaneously undergoing treatment, considerable personal attention is required to ensure success, since the numerous factors militating against a perfect result are not all capable of scientific control, and therefore a skilled and reliable set of operators working consecutive shifts is a valuable asset if quite extensive and serious failures are to be avoided. The study of the correct temperatures and speeds for varying carbon contents and wire sizes is one of the most interesting problems which occurs in practical metallurgy, and very close co-operation between the scientific control assistants and the operatives is necessary, particularly as modern steel-making conditions necessitate a constant watch on both new and old factors which may cause periodical trouble, which is often difficult to overcome instantly.

Naturally when the question of heating accurately is so actively connected with successful operation, numerous experiments have been tried out to bring about the best results attainable with the least possible difficulty, and it is proposed to compare the oldest English method and some of its modifications, with what is understood to be the latest American achievement in the process of "patenting" steel for wire drawing purposes. The original intermittent method employed the direct flame contact with the material, and although thermal efficiency was thereby kept high, ordinary coal-firing was not reliable enough due to the fluctuations, and producer gas has had to be substituted, where oil is not readily available. The next step was to enclose the heating chamber into a muffle form, which gradually lost its round shape and became elongated to the present length of fifty feet, which is almost universal in the continuous furnaces. From seven to ten fire-places were often needed to keep up the temperature required when coal or coke firing was adopted, but careful observation soon enabled three properly placed deep fires to perform the heating operation through the firebrick muffle walls. Instead of the curved muffle, many furnaces now employed for "patent-

ing" are fitted with tubes or "quarries" which are formed by setting closely together a number of four-hole bricks lengthwise to the desired overall dimension, and side-by-side to take thirty or forty wires, passing two through each channel. The deepening of fire-places eventually developed into proper gas producers for firing, and by the use of deflecting flues, one central gas source can heat thoroughly from end to end the passages beneath and above the muffle. One very appreciable effect of the recent coal strike in England has been the replacement of the coal-fed producers by simple type oil burners, which are not only much more efficient as heaters and easy to control, but have proved exceedingly economical in operation. The expense of town gas in England has so far prevented the adoption of this form of heating for patenting furnaces, and the same restriction applies to electrically operated furnaces, but both methods have been put into successful operation in America. The abandonment of the electrical heating in America was brought about by the excessive cost, in spite of the excellent quality produced, particularly when it was compared with the most modern method of town gas burned in the open heating chamber under the conditions of radiant heat from the surface combustion method. The special advantages of this will be enumerated later.

Bee-hive furnace. The old English method of patenting rods and wire is still practiced in certain works at the present time, and when skillfully conducted by long practiced hands, it certainly yields material which gives remarkable results when drawn into high-strain wire, particularly in regard to torsional test values, but the slightest carelessness, or wilful neglect can yield most non-homogeneous material with unreliable and inconsistent physical test results. Neglected furnace conditions and deficient regeneration of the heat of the spent gases also may lead to trouble, but the well-designed bee-hive with good gas producers maintaining a steady supply of gaseous fuel are difficult to beat for quality of production, although the quantity of their output per man-hour is certainly not large. The arduous and hot task of loading and unloading the single furnace, is a job which not many men can be brought to face year in and year out.

When the burning gases leave the combustion chamber placed at the back of the conical or bee-hive shaped heating chamber, they

circulate upwards around a fireclay bollard set in the middle of the hearth, and then escape to the checkers for regenerative purposes. The coil of rod or wire to be treated is placed on a swift, set down somewhat to the left hand side of the furnace outside the small aperture through which the first end is guided by the operator until it is hooked to the top of the bollard's circumference. A pedal is depressed which engages the external gearing to rotate the bollard inside the furnace, and the whole coil is guided wap by wap on to the bollard, an operation which requires careful watching all the time, and occupies from two to five minutes depending upon the gage, and thus the length of the two hundred pound coil which is the weight commonly treated in one run. Full gas is put on, and from fifteen to twenty minutes time is taken to raise the temperature of the outer layers to between 1740 and 1830 degrees Fahr. (950 and 1000 degrees Cent.) Another similar period elapses in raising the temperature if required to 1920 degrees Fahr. (1050 degrees Cent.) and then the coil is ready to be drawn out in the reverse direction to that of its entry. During the waiting time, the workman has connected a stout wire to the projecting end of the coil and passed it along a 100-foot iron channel, about one foot wide and provided along its entire length with small heaps of sand through the center of which the wire passes to a collapsible swift, capable of being driven at any desired speed. At this extreme end the worker takes his place and winds the coil of wire out of the furnace, over several small guide pulleys to break off the somewhat excessive scale, and then through the heaps of sand to the far end of the channel and thus, still hot, on to the swift. The cooling is partly accomplished by the sand heaps, and to prevent the portion in contact with the wire from becoming too highly heated and thus defeating its object, a hand wheel is slowly turned by the operator to move the hot wire from side to side of the channel by means of guide forks. Two mirrors placed in horizontal periscope fashion enable the workman to observe at what position in the channel length the visible red disappears from the wire, and good patenting is reckoned to accompany the cooling through the recalescence point down to this temperature within half the length of the passage to the collapsible winding swift, the speed of which is regulated accordingly to suit the size of rod or wire under treatment.

Obviously the sand used in this process must be perfectly dry, otherwise an excessively quick cooling would result in places, and brittle places, due to the formation of martensitic needles instead of sorbitic crystals, would result. Neither must there be too much sand, nor the heaps be placed too close together, or the most desirable rate of cooling would not remain consistent throughout any one run, and again irregularity would result. The most obvious discrepancy however arises from the fact that as it takes an appreciable time to get the coil both in and out of the furnace, the first end which goes in, is naturally the last to emerge, and therefore it may have been in the furnace at the highest temperature, as much as ten to twenty minutes longer than the other end. Thus a considerable difference is likely to occur, and often does occur, between the size of the crystal grains at the back and front ends of the wire after it is drawn down. This leads to quite large divergencies in the physical properties, and the reason is perfectly obvious from a simple microscopical examination, which reveals the relative size of crystal grains produced, and the long and short fiber wire resulting from the extremes when drawn down by several passes. In spite of this draw-back, however, close attention to the furnace temperature control, and of the withdrawing speed, enables comparative uniformity of product to be regularly achieved.

Continuous Furnace. This form of patenting furnace appears to have been developed about the same time as the tubing furnace was introduced for softening the wires being galvanized by the Bedson continuous process. The temperatures required for patenting were somewhat higher than for annealing, but the construction of the muffle type of heating chamber with tubes for the passage of the wire is exactly similar, and readily lends itself to the recuperative principle of utilizing the heat of the escaping products of combustion on their way to the chimney stack. The coils of rods or wire are placed horizontally on swifts at one end of the furnace, and are drawn through the tube-like passages in the muffle at the required speed to suit their carbon content and the gage size. After they emerge from the hot end of the furnace at a bright red heat, well over the recalescence point, they are cooled in either of three ways before being coiled on the revolving blocks of the winding frame. This was formerly steam driven, but is now most commonly controlled by a variable speed motor acting through a

worm drive which gives much smoother working than old fashioned cut gearing with its numerous bearing blocks conveying the motion to each of the blocks, arranged in pairs on the 10 to 15 shafts. For the highest carbon steels, it is usually sufficient to let the hot wire emerge into the atmosphere to achieve the requisite cooling to effect the "patenting," but it must not be too rapid a transit through this range or a partly martensitic structure persists, and brittleness results. For certain purposes and in some of the medium carbon ranges, it is found advisable to perform the cooling by dipping the emerging wires into a bath of molten lead kept about 930 degrees Fahr. (500 degrees Cent.) as this enables the steel to cool rapidly enough through the first part of its transition, and then a much slower cooling takes place when it comes out of this molten metal bath and is wound on to the frame blocks. Sometimes quite low carbon mild steels are passed through the patenting furnace, but as neither air nor lead bath cooling would be rapid enough to retain the carbon in the fully dispersed and sorbitic condition, it is necessary to dip the wires close to their point of exit from the furnace into a trough of water, kept circulating to ensure the maximum amount of chilling.

When the "quarries" or tubes are kept open at both ends to the access of air whilst the wire is passing through, quite a considerable amount of surface oxidation takes place, and the percentage of scale formed may easily attain 3 to 5 per cent. This not only amounts to an undesirable tonnage of waste product in a year, but means that there is an appreciable amount of surface decarburization in the wires, and cleaning operations are retarded and excess of acid is consumed in that process. Numerous attempts have been made to produce non-scaling rods or wire, and apart from the obvious method of sealing the ends effectively against the entry of air which is in some cases practiced, a useful method consists in arranging for a slight pressure of the gases in the combustion chamber below the muffle towards the exit end. This ensures a slight leakage of the partly consumed gases into the tubes, and a short luminous flame travels along with the wire to the outlet and preserves a neutral if not altogether a reducing atmosphere. In this way scale is very much reduced, the percentage formed not exceeding one per cent, with a resulting gain all around. The wire drawer however, who is accustomed to have

his high carbon patented wire slightly decarburized at the surface has to modify his passes slightly owing to the harder skin of fully carburized metal instead of the ferritic structure formerly provided for him.

Double treatment is sometimes advocated for steel which will not patent perfectly with only one passage through the tubing furnace, but with a knowledge of the steel composition, there is no need to do the treatment twice, it should be run at such a speed and temperature that the desired internal structure is attained by a single heating. For very irregularly shaped rods, it might prove an advantage to give them a breaking down or roughing pass through the draw plate to ensure that the sectional area was uniform and thus ensure equal cooling rate at all parts of the coil length, but this entails an extra cleaning operation, and is usually obviated to save cost, just as in the case of eliminating double patenting.

Gas-fired Furnace. The latest and highly economical utilization of town gas for heating the patenting furnace depends for its success upon the principle of what was at one time called "flameless" combustion by one of its earliest users. The principle consists in burning a mixture of compressed air and gas which is passing out of the special nozzle at such a speed that the velocity is greater than the rate of flame propagation, and thus there is no firing back which would result in an explosion. The combustion is maintained due to the velocity of the mixed gases falling off as they spread out in a cone-shaped formation, and to obtain the maximum heating effects of this burning gas it may be directed against a bed of granulated refractory material where the combustion takes place at the surface and in the interstices of the particles, which may be raised to an almost incandescent heat. Another method, which is the one employed for heating some of the most recently adopted patenting furnaces in America, consists in locating the burner nozzle in the axis of a cylindrical tunnel, the walls of which are made of a highly refractory clay so that combustion takes place at or near the surface of this material. A number of these surface combustion burners is placed along each side of the furnace in which the hearth is heated by radiation effect only, and no enclosed muffle is needed, the wire being passed through the heating chamber exposed directly to the heat of the

arch. It is even possible to dispense with the use of secondary air, as by the use of the latest type of burners the air is induced to form the desired mixture by the injection effect of the gas compressed to 10 pounds per square inch, when it enters the burners. The atmosphere can be maintained so nearly reducing that the scale production never exceeds 0.9 per cent of the rod weight, and improved patenting due to this method accounts for a scrap and rejection reduction from 9 to just over 1 per cent.

In one battery of six furnaces recently installed of this surface combustion type, each of the furnaces is 50 feet long, with a solid hearth four feet wide and with only eight inches to the spring of the arch. Nineteen burners are arranged along the sides, but only about one half of these is required to maintain the working temperature; once that has been attained, it requires a very short time from lighting the burner until a working temperature is reached. Since there are no flues needed, the furnace construction is exceedingly simple, being set down on a solid concrete bed, and repairs are practically negligible over long working periods. The insulation lining consist of 4½ thicknesses of special firebrick, backed with 9 inches of ordinary firebrick. There are usually 30 wires in the run, but with heavier rods the number would be reduced depending upon gage size. Pyrometer control of the varying ascending temperatures along the furnace length is readily effected by the aid of three pyrometers, indicating the temperature at the entrance, exit and another point one third along from the outlet. Thermostatic control of the temperature is incorporated in the system so that the autographic records seldom show more than a 5-degree Fahr. variation up or down, in spite of the great changes in atmospheric temperature. In patenting 0.6 to 0.7 per cent carbon wire between 9 and 15 gage size (0.144 to 0.072 inch diameter) the average gas consumption is stated to be about 1800 cubic feet of 525 B. t. u. town gas per hour, during which period 1200 pounds of wire can be given patenting treatment. With gas costing around 60 cents per 1000 cubic feet this is a distinctly paying proposition, and with the aid of indicating lights from the pyrometer control room, only one furnace man is needed to look after the whole six furnaces.

Patenting Practice and Faults. Examples selected from actual works' practice may be of interest in illustrating some of the faults

formerly mentioned, and a few others which have developed in the subsequent working up the patented material, and which are more or less directly attributable to the results of imperfect conducting of the heat treatment process. Right at the commencement it should be stipulated that for the very highest degrees of perfection in the patenting process it is of no use to select an inferior steel, or one which is "ghosty," segregated or contaminated with an excessive amount of solid nonmetallic inclusions, commonly referred to as "slag" although not always coming from that source. When the piped portion of an ingot has been rolled down into a billet and insufficiently cropped the "rose" indication of the cropped end should be looked for and such billets eliminated at the rod mill, but if even a portion of such a segregated, often high carbon, portion gets into a length say of one end of a rod coil, then patenting will not succeed in getting rid of the defect, as it might be expected to do by diffusion. Nonmetallic inclusions interfere when too numerous, by seriously impeding the rate of crystal grain growth, so that a clean steel patents successfully much more regularly and uniformly than one which is decidedly "dirty." The establishing of a standard which will be acceptable for high-strain rope wire for instance, is a matter of considerable importance, and yet attended with difficulty, although many reliable steel makers recognize this and provide remarkably good high carbon products for this purpose. Phosphorus-rich patches extended by rolling and drawing into "ghost" lines are very effective in preventing the uniform diffusion of the carbides during patenting, and considerable deficiency in the physical properties can arise in this way, which is almost impossible to overcome by any reasonable prolongation of the tubing time.

Quite a number of failings may arise from the purely mechanical side of the furnace operation. Thus if the temperature of the furnace is not kept gradually ascending to very close to the outlet end, the wire may commence cooling while still in the tube, and thus pass too slowly through the recalescence point, with the result that the desired sorbitic structure may be partly let down to laminated pearlite, and this does not draw nearly so well nor give such good physical tests as the maximum sorbitic structure. The cooling may even be slow enough, to permit some free ferrite to form around the crystal grains of the higher carbon steels, and

this sets up a sufficiently nonhomogeneous structure to lower the valuable properties of wire after drawing down to the desired final size. Too slow passage through the furnace will tend to increase the amount of scale produced, and as an extreme example of this the case of a piece of broken rod which remained two days in a furnace before it could be removed showed that the original 5-gage (0.212 inch diameter) had increased to 0.315 inch chiefly composed of magnetic oxide of iron, and only an inner core of solid metal 0.080 inch diameter was left like a thread holding the mass together.

The desire for large output sometimes fosters the fault of driving too quickly, with harmful results. To maintain the temperature in such a case it is easy to get the furnace too hot, and the effect is either to induce the brittle martensite structure which snaps the rods in bending round the 24-inch winding blocks, or if the temperature cannot be kept up, insufficient carbon dispersion is effected in the short time of passage through the tube and a non-patented structure results, or else an incomplete growth of the crystal grain size may be brought about, which is only slightly less deleterious in its after effects. There is no doubt that the best rope wire structure is one in which long fibers are discernible, and only large crystal grain size in the patented rod will give this result:—a small grain size obviously yielding a short fiber structure for an equal amount of reduction in sectional area by the same number of drawing passes through the die-plate. The vexed question of overdrawing in patented steel naturally resolves itself into a question of crystal grain size in the original rod, because a large size of crystal grain will extend much further without beginning to suffer disruption than a smaller grain, and this is not remedied by the process of reversing the direction of drawing the wire at say the ninth pass for an eleven-hole job, because the slipping apart of the crystals at the grain boundaries will actually have commenced around the small grains without it having done so around the large ones. When this fault is not revealed by any of the commonly applied physical tests to the plain drawn wire, the slightest deficiency in the perfectness of patenting is rapidly revealed by a low temperature heating, such as that applied in galvanizing, and although the actual drop in tensile strength value may not be more than 10,000 pounds per square inch, the de-

crease in the number of torsions which the wire will stand after galvanizing, or even after simple immersion in boiling water, is quite remarkable in certain cases, whereas a thoroughly well patented wire will not lose nearly so great a proportion of the number of twists before fracture under torsion.

Details of Specimens. In the low carbon steels which are patented and water-quenched, the complete diffusion of the carbide not only enables the wire to be drawn to suitable small sizes without fear of breaking up in the process, but the uniform dispersion of the sorbite allows a remarkably high tensile strength to be attained by this material. There is very little free ferrite in addition to sorbite in this type of structure. That the quenching can be made from too high a temperature, i. e. exceeding the best temperature of 1795 degrees Fahr. (980 degrees Cent.) for a 5-gage rod, is demonstrated by the acicular structure found in a rod which had been drastically quenched from 1875 degrees Fahr. (1025 degrees Cent.) and which was too brittle to coil until the temperature was dropped down at the exit end of the furnace. The ill effect of phosphorus segregations, is responsible for the "ghosty" structure of water-treated wire. In this structure the carbide diffusion has been completely impeded to the detriment of the physical properties. Instead of reheating to bring about the desired structure for upholstery spring wires by water treatment, it has been sometimes successfully attempted to produce this desired form by quenching the coils of rod in rapidly moving water immediately after rolling in the mill. The finishing temperature may be very nearly that of the patented rod, but the requisite grain growth has not had time to develop, and thus a slightly less useful combination of physical properties is achieved.

In the medium carbon steels, the lowest range of carbon content which is usefully patented embraces the 0.35 to 0.55 per cent carbon content, and one interesting product falling within this range is the great variety of spoke wires. They are usually specified within the limit of 145,000 to 168,000 pounds per square inch tensile strength, and it is often a problem to select the right method of manufacture to give this in a suitably treated steel which has, after drawing, to stand cold-heading and sharp right angle bending when being made into spokes. An example of the lower range which had proved brittle to bending in No. 15 gage is shown

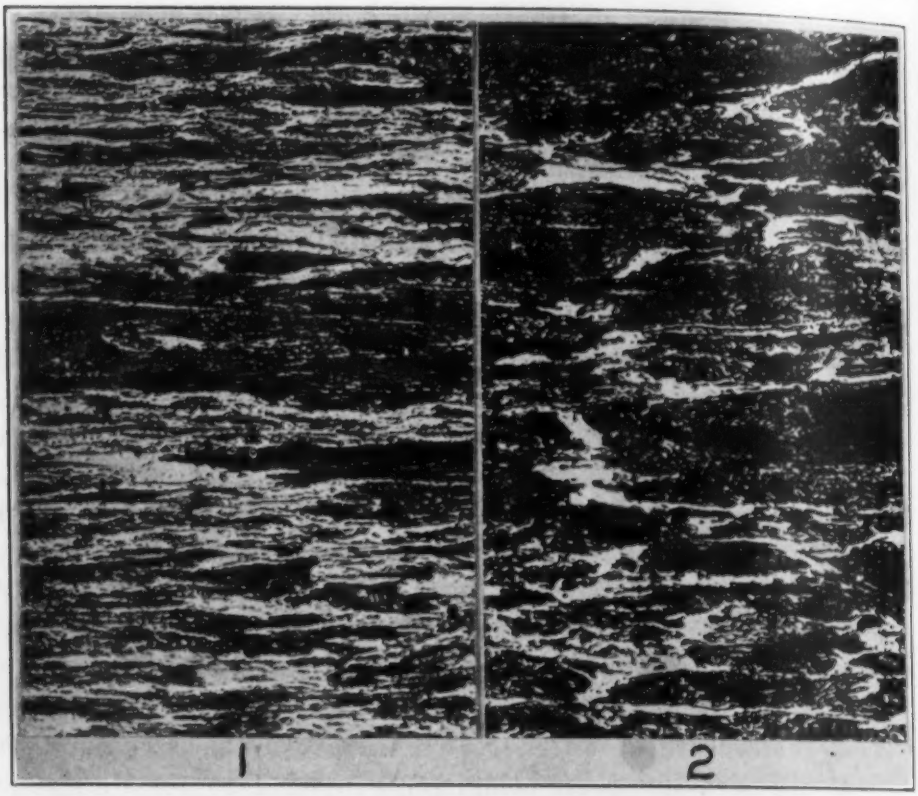

Fig. 1—Irregular Grain Size in Defective Cold Heading 15-Gage Spoke Wire of Medium Carbon Steel. Mag. 500 x. Fig. 2—Satisfactory Structure of Good 15-Gage Spoke Wire of Medium Carbon Steel Showing Long Fiber in Good Grain Size. Mag. 500 x.

All Specimens Shown in These Photomicrographs Were Polished and Photographed in a Longitudinal Section Cut Medially Whenever Possible. The Etching Medium Found Most Advantageous to Develop the Pearlite-Sorbite Structure was Picric Acid Dissolved in Absolute Alcohol and Given a Slight Mineral Acid Acidity with 0.05 Per Cent Nitric Acid.

micrographically in Fig. 1, and the reason is not far to seek in that the patenting temperature has not been high enough, resulting in a nonhomogeneous structure, too small crystal grain size, except in isolated places, and consequently a certain amount of overdrawing effect in attaining the diameter of 0.072 inch, which is not counteracted even by the moderate manganese, 0.48 per cent with the carbon 0.38 per cent. For comparison, the structure of a satisfactory wire of 15 gage is shown in Fig. 2; with practically the same carbon content, but with much more satisfactory physical properties which can be directly attributed to the correct structure of suitable sized crystal grains to give a longer fiber wire as the final product of drawing, with the requisite toughness and capability of cold-heading without splitting and also bending without cracking.

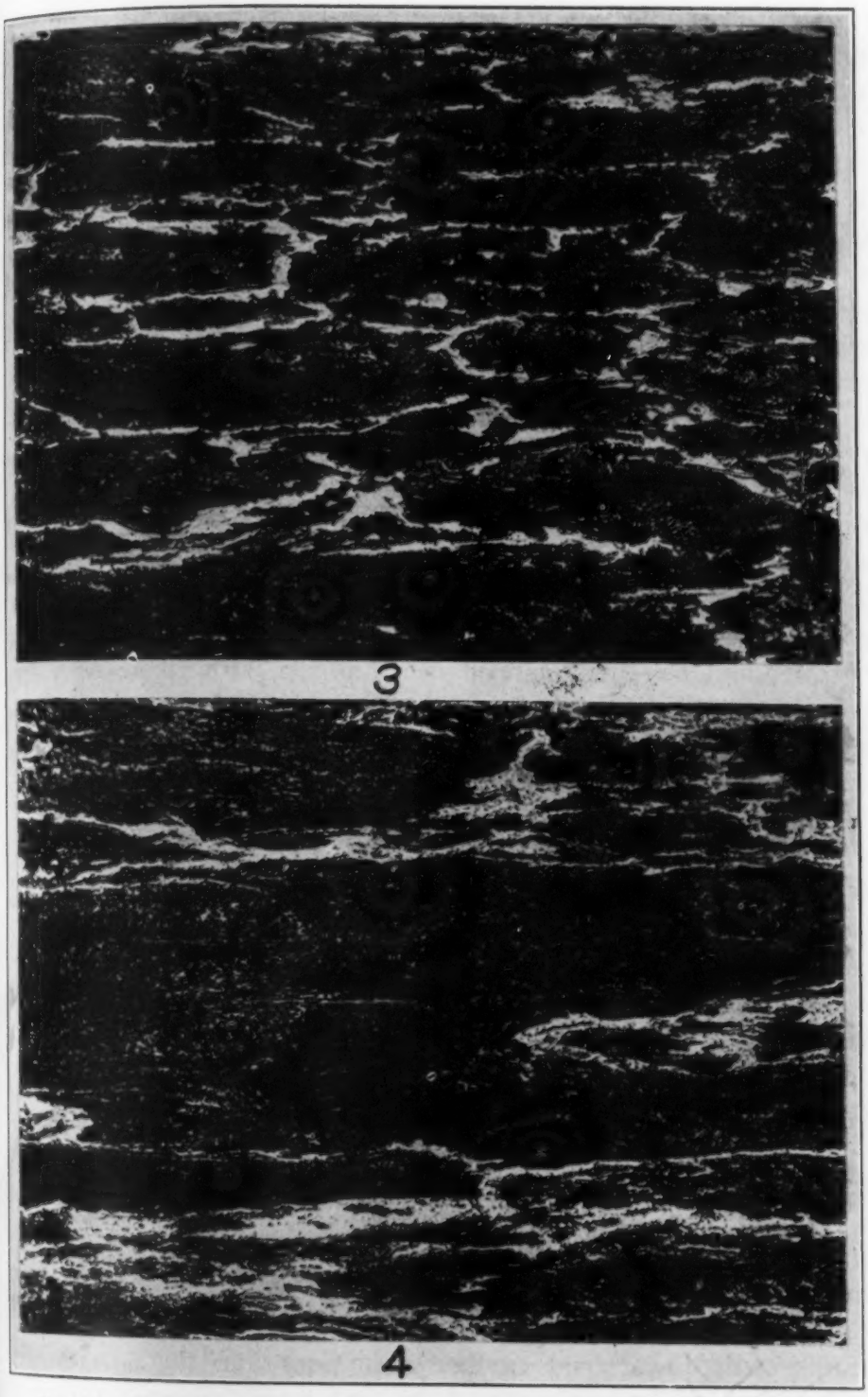

Fig. 3—Good Sorbitic Structure of 15-Gage Spoke Wire of Medium High Carbon Steel of Suitable Grain Size and Fiber Length. Mag. 500 x. Fig. 4—Excessive Grain Size in 15-Gage Spoke Wire of Medium High Carbon Steel Failing Heading and Bending. Mag. 500 x.

With a slightly higher range of carbon content between 0.45 and 0.50 per cent, the heat treatment in regard to lower temperature of patenting as compared with the lower carbon steel has to be carefully watched, and whereas the latter can usefully be conducted at 1560 to 1615 degrees Fahr. (850 to 880 degrees Cent.) the former can easily develop too large a grain size at this range, and it is preferable to lower it to 1470 to 1545 degrees Fahr. (800 to 840 degrees Cent.) and to regulate the speed in say a 5-gage rod to approximately 25 feet per minute, compensating for the enlarging of the coil diameter as the block fills up, or else to use the parallel-arm blocks on the winding frame, and obviate this difficulty of variable speeds in case all the coils passing through the furnace are not at the same stage. Figs. 3 and 4 represent the microstructures of similar wires all in a 15-gage, and, although their analyses are similar, and the tensile properties of all are good, there was considerable difference in their practical performance in manufacture. The slightly lower tensile in Fig. 3 accompanying the suitable grain size and length of fiber of this well patented wire gave the best heading and bending performance, but the wire whose structure is given in Fig. 4 was of such a large grain size originally and somewhat nonhomogeneous as well, that it failed in both heading and bending operations.

The variation which can sometimes arise in the grain size of the same coil by patenting in a furnace which has not been working uniformly and the temperature of the exit end has been fluctuating, is clearly indicated by the photomicrographs of a 0.50 per cent carbon steel rod shown in Figs. 5 and 6 both at the same magnification. In this case the first end through has not developed the full grain size needed for the requisite fiber length when drawn down to wire. The galvanized wire drawn from such a coil gives widely varying physical tests, particularly in regard to torsional values, while the tensile strength and number of twists before galvanizing were practically identical, the end of the coil with the small grain size lost over 11,000 pounds per square inch tensile and 80 per cent of the torsional value, after galvanizing, and the large grain end lost barely 6700 pounds tensile strength, and only 15 per cent of the twists. The reason was obviously that the big grains could have stood further reduction than the 6-gage sizes in four passes from No. 5 rod without harm, whereas the same

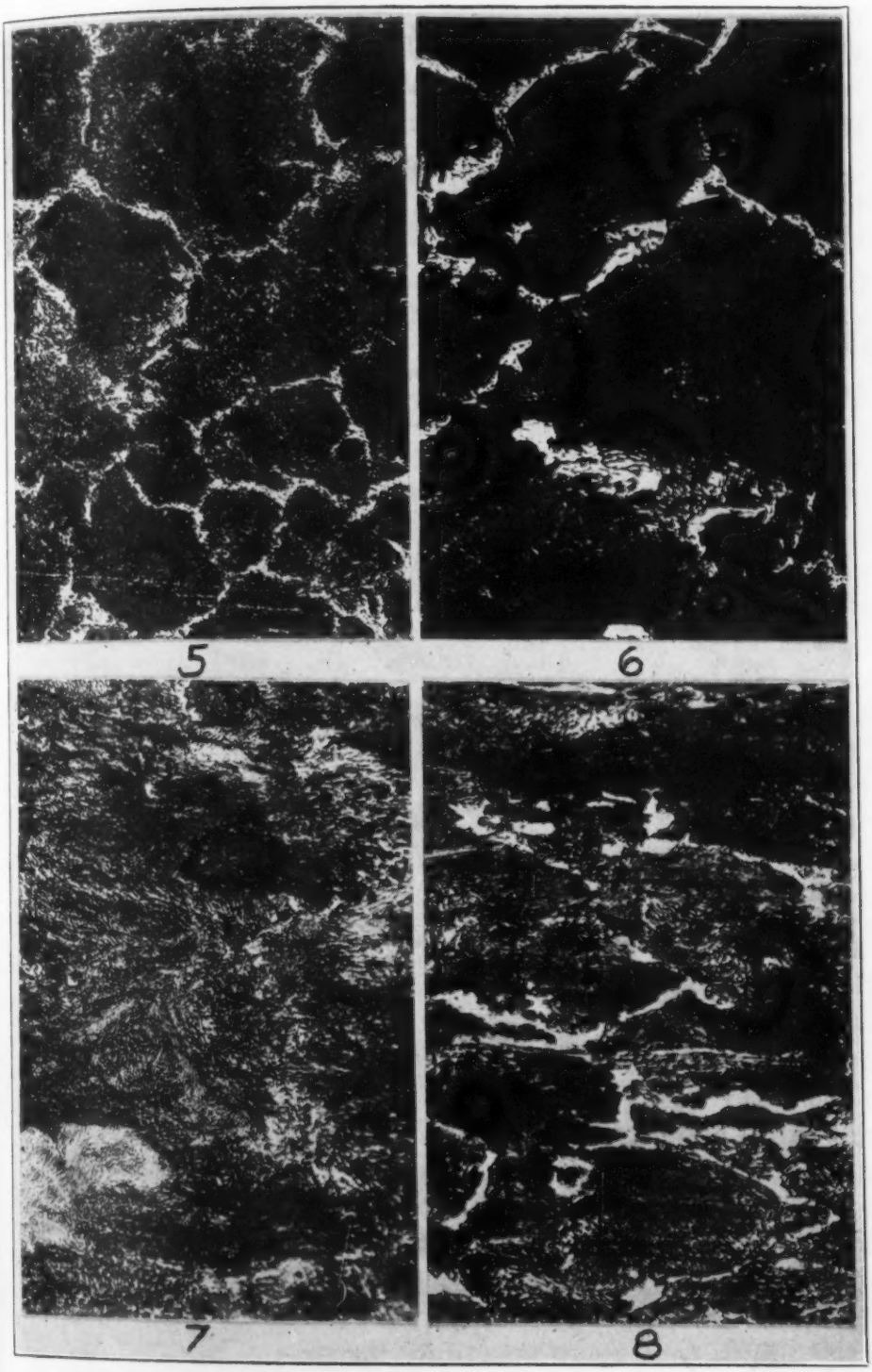

Fig. 5—Too Small Grain Size in Imperfectly Patented 5-Gage Rod of Medium-High Carbon Steel. 500 x. Fig. 6—Satisfactory Grain Size in Completely Patented 5-Gage Rod of Medium High Carbon Steel. 500 x. Fig. 7—Completely Sorbitic Structure of Patented Medium-High Carbon Steel, Cooled in Lead Bath. 500 x. Fig. 8—Partly Ferritic Structure of Patented Medium-High Carbon Steel, Cooled in Air. 500 x.

number of passes had brought the small grain end perilously near to the stage of overdrawing, the ill effects of which were not fully revealed until the tempering action of the zinc bath had developed them, without doing so to the large grain size wire.

The importance of the rate of cooling in making a perfectly patented wire is shown by the relative performances of two springs made from half round section in 0.50 to 0.55 per cent carbon steel.

Table I
Physical Properties of Patented Wires

Fig. No.	Diam. In.	Carbon per cent	Manganese per cent	Tensile Strength Pounds per sq. in.	Twists in 8 in.	Magnification Diameters	Remarks
1	0.072	0.38	0.48	179,000	10	500	Irregular grain
2	0.072	0.38	0.55	168,000	38	500	Good grain and fiber
3	0.071	0.43	0.59	163,000	37	500	suitable grain size
4	0.072	0.45	0.60	161,000	20	500	too large grain size
9	0.093	0.72	0.68	178,000	2	500	partly pearlitic
10	0.093	0.72	0.68	207,000	21	500	Good grain size and long fiber

In order to retain its stiffness after a great number of repetitions of alternating stress of quite low value, the correct structure required is one which is completely sorbitic, without any free ferrite being left at the grain boundaries. Such a microstructure is shown in Fig. 7 which has been bright-drawn 5 holes from patented wire, which had been given a roughing pass before heat treatment. A similar wire got up in the same way but which had not been cooled through the recalescence point sufficiently rapidly, and this showed some intergranular ferrite, (Fig. 8) was not successful in operation, as the springs made from this wire failed after a few days' use to hold up to their duty, in spite of the fact that the physical tests and analysis classed the two materials as practically identical. This is a case in which it is sometimes necessary to re-

sort to lead bath cooling instead of the usual air cooling of the patented wire in order to bring about the best form of retention of the sorbitic structure.

Coming to the higher carbon steels such as are used for the highest grade of rope wires, hawsers, springs and stone cutting wire, the importance of perfect patenting is very great, as serious consequences may arise from a failure in service of unsound material. A clean, degasified steel is a primary necessity, and as a perfectly slagless cast is not commercially possible, it is advisable to insure that the steel billets from which the rods are rolled have the slag particles as small and as uniformly distributed as they can be made.

Very useful information can be acquired by following carefully, by means of the microstructure, the course of the crystal grain deformation at each successive pass of the patented rod to finished wire. In this way the development of the requisite fiber length can be watched, and as idea of the requisite grain size to give the longest possible fiber in the final product can be quickly arrived at. By stopping the block just before the last end passes through the die and breaking off the portion including the conical construction of the wire, perfectness or otherwise of the "seating" or "bearing" of the wire in the hole of the plate can be examined, and also the concentricity of the "flow" of the metal grains all round the circumference to make sure that this is uniform, and not one sided as may happen with a bad "lead-in." Some crystal grains follow the flow of the metal and become elongated, while others, differently oriented, resist deformation and set up what may be likened to "back-waters" in the stream. A 0.72 per cent carbon rod patented in No. 0 gage was reduced 78.4 per cent in cross-sectional area by the following holing in diameters

Inch	0.315 → 0.275	→ 0.238	→ 0.211	→ 0.184	→ 0.168	→ 0.150	→ 0.134
Reduction Per Cent	23	25	22	23	16	19	19

In this particular case the wire has undergone reduction of size in six holes before the fiber has begun to develop the parallel structure, so essential in securing freedom from eventual breakup and from low torsional values in the final size. The final tensile strength of such wire ranges from 224,000 to 246,000 pounds per square inch.

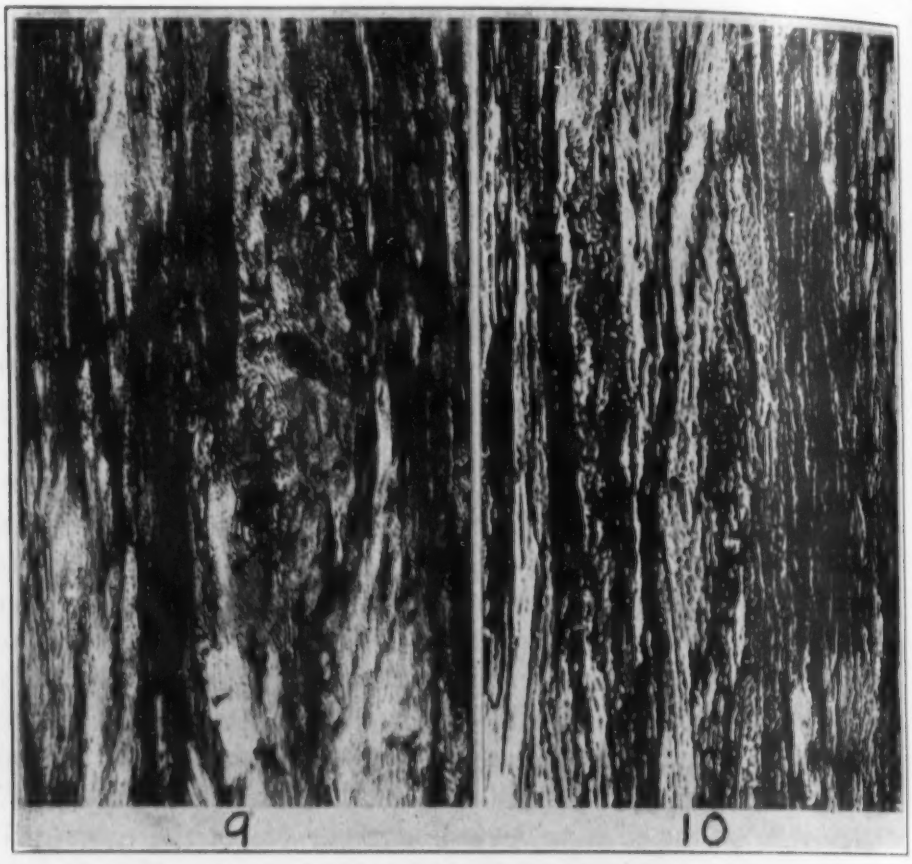

Fig. 9—Partly Pearlitic, and Large Grain Size of High Carbon Steel Wire Giving Low Torsion Number. 500 x Fig. 10—Long Fiber Structure and Good Grain Size of Carbon Steel Wire Giving Good Torsions After Galvanizing. 500 x.

In the case of galvanized hawser wire required to give from 200,000 to 213,000 pounds per square inch tensile strength with a high torsional value from 0.70 per cent carbon steel, patented as wire before the final set of die-plate passes, it is useful to connect as in Figs. 9 and 10, the relation of fiber length arising from various grain sizes to number of twists in the final 13-gage wire. With very slight variation in the tensile strength values the two wires illustrated by their microstructures gave respectively 2 and 21 twists in an 8-inch test piece length, and the first has partial pearlite decomposition in the broad bands, but the second has perfectly sorbitic grains of great fineness and considerable fiber length.

The "letting-down" from all sorbitic to an even partially pearlitic structure in high stress rope wire is very deleterious to its properties, especially the resistance to torsion. (This is clearly shown in Fig. 13 at 1000 diameters magnification.) In this case

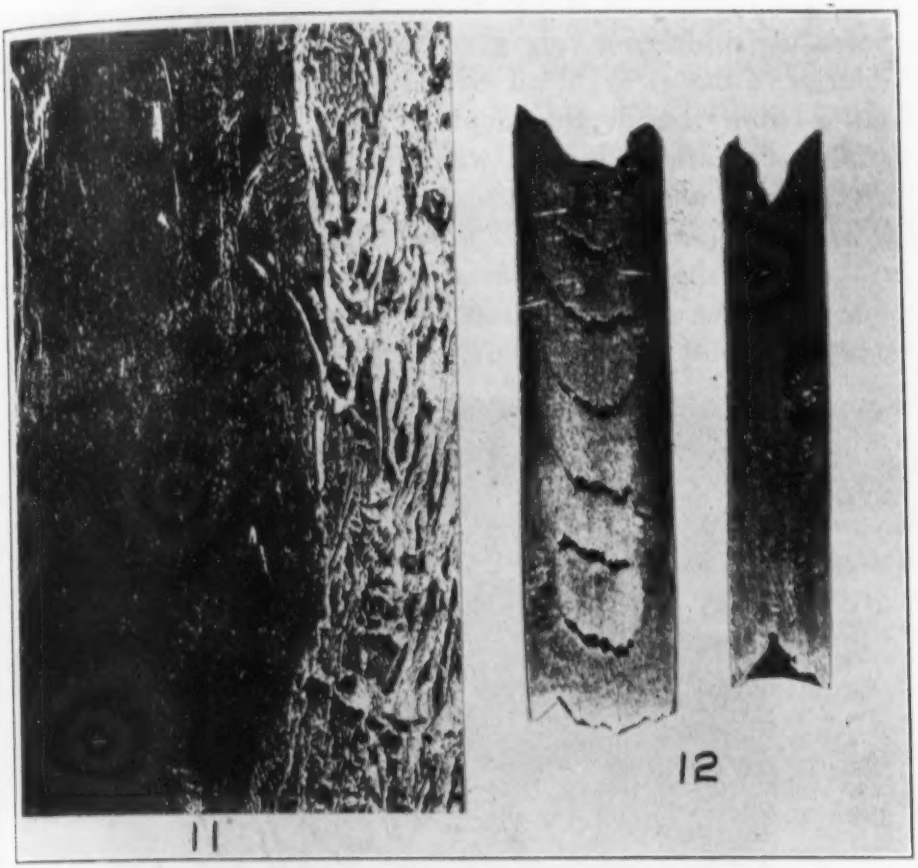

Fig. 11—Deep Decarburization of High Carbon Steel Rod Patented Too Long at Too High a Temperature. 200 x. Fig. 12—Medial Section of Cuppy Steel Wire Which Failed Due to Deleterious Segregations of Carbon and Inclusions in the Core. Enlarged 3 x.

the front end of the rod from a bee-hive patenting furnace was not led quickly enough into the heaps of cooling sand, with the result that frequent occurrence of perfectly pearlitic patches could be observed enclosed in the generally sorbitic ground mass, which caused the wire to break up with a cuppy fracture at the fourth hole pass. Even if it had been successfully drawn to the final diameter desired it would have been most likely to fail in the torsion test with a low number of twists, due to lack of homogeneity in structure, and because of the ragged nature of the fracture, which would probably "fly" with a fiery spark.

Breaking up of patented wire, with a "cuppy" fracture does not always depend upon the formation of this structure consequent upon too slow a rate of cooling and pearlite resulting. One other infrequent cause in the case of high carbon (0.75 per cent) steel

wire was found to be due to excessively high temperature and slow patenting, which not only gave rise to enormous grain size in the interior of the wire, but an excessive amount of surface decarburization to a considerable depth. Such an undesirable state of affairs is shown in Fig. 11 which is No. 0 gage rod which broke up "cuppy" and the very great rapidity of carbon content change is certainly remarkable and proof of bad practice.

One of the most prolific sources of cuppy fractures in wire, apart from cases of overdrawing, is the presence of a markedly segregated portion in the core, which because of its higher carbon

Fig. 13—Pearlite Patch in Sorbitic Structure of High Carbon Steel Rod too Slowly Cooled in Patenting. Mag. 1000x.

content, often coupled with inclusions, will not extend in length to the same extent in drawing as the lower carbon outer portion of the wire. In this way internal rupture can easily be caused, and it is usually quite readily detected either by the break up of the wire in the drawing operation, or in testing by bending or twisting. Fortunately it is generally found near one end of a coil of wire, not always as bad as the instances shown in Fig. 12, but if such internal faults were to remain undetected in a length of wire rope the consequences might easily be very serious.

In conclusion it is hoped that some interest has been found to attach to the problems of producing "patented" steel wire for various purposes by tracing the origin and development of the process in various forms of heating furnace, culminating in the

latest gas-fired and pyrometrically controlled plant in the U. S. A. From the numerous photomicrographic illustrations it is probably obvious how important and useful is this method of controlling and inspecting the works' product to insure that only perfectly satisfactory and trustworthy material is used to meet the varied specific purposes to which the different classes of patented steel wire can be applied.

DISCUSSION—DEVELOPMENT OF HIGH SPEED STEEL HACK SAWS OR CUTTING OFF SAWS

(Continued from Page 616)

milling cutters is now almost universal. Furthermore some excellent researches made recently by Mr. Herbert in England show that the cutting points of a hack saw in operation do reach a red heat. It would seem therefore that the increased cutting ability of a high speed saw can be attributed to its property of red hardness rather than carbide nodules. Another indication that such is the case is that while a high speed steel saw contains considerably fewer carbide nodules, visible under the microscope at least, than does such a steel as Mr. German mentions, the high speed saw can be operated at feeds and speeds which quickly ruin one made out of the low tungsten steel.

Mr. German points out the accepted reason for the gradual increase in the hardness of the saws standing at room temperature after hardening. Possibly I did not sufficiently emphasize the point brought out in Table I which I considered of most interest, namely that the "aging" is still going on even after the Rockwell hardness had nearly reached stability, and also the considerable plasticity of the steel in this same condition of high hardness. Further studies indicate the interesting possibility that to attain maximum hardness after tempering the steel should best be allowed to age at room temperature for some time before tempering. The ordinary hardness test does not seem to be sufficiently sensitive for studying these changes and therefore work is in progress using magnetic analysis.

Mr. German criticizes the comparative performance results as given in Tables II and III as being made under wrong conditions and as being incomplete. As indicated in my paper its intent did not include the field of relative economy of different kinds of hack saw blades, a discussion of which would constitute a separate paper in itself. The two tests summarized by me were included to give, as I stated, a general idea of relative performance. And in fact the speeds and feeds shown were the result of several trials and gave the most efficient results for both types of blades cutting the particular material noted.

ALLOY STEEL FOR BOILER CONSTRUCTION

By Charles McKnight

Abstract

The rapidly extending use of nickel steel for boilers in the past few years has resulted in a compilation of facts and conclusions derived from investigations to determine the suitability of this material for such applications. These are apparently worthy of being presented at this time.

Boiler pressures a few years ago rarely exceeded 300 pounds per square inch. Today there are stationary boilers operating at 1400 pounds per square inch and even higher, while in locomotives the conservative 200 pounds per square inch is being raised step by step until now there are locomotives operating with pressures of 500 pounds per square inch.

The present rapid trend toward large units, high pressures and high superheat temperatures in boilers of all types has engendered the need for better boiler materials. In marine and locomotive boilers, space and weight limitations necessitate a material of greater strength for equal or less weight. In the stationary type of boiler, where these limitations are not so pressing, the same need has arisen through the impracticability of fabricating ordinary steel plates of the thickness necessary.

Use Of Nickel Steel In Boiler Construction

TWO years ago the Canadian Pacific railway in designing some new locomotives desired to increase the capacity and efficiency of their motive power without materially increasing the total weight. This could be done by increasing the boiler pressure 25 per cent but to do that without increasing the thickness of the boiler plate appeared on the face of it to be an impossibility. But the Canadian Pacific successfully accomplished the apparently impossible by taking a step that they had been investigating and considering for some time. This was the use of 3 per cent nickel steel boiler

A paper presented before the semi-annual meeting of the society held in Montreal, February 16 and 17, 1928. The author, Charles McKnight, a member of the society, is metallurgist with the development and research department of the International Nickel Company, New York City. Manuscript received January 25, 1928.

plate of 70,000 pounds per square inch minimum tensile strength. Approximately 30 per cent stronger than carbon steel, its use permitted an increase in boiler pressure from 200 to 250 pounds per square inch without any change in thickness of the boiler plate. A total of 44 locomotives were thus constructed for this company in 1926; 24 Pacific type and 20 Mikado type. They have fully justified the expectations of improved performance and efficiency.

Such an unprecedented step on as large a scale as this immediately aroused countrywide interest, not only among railroad officials but among builders and users of other types of boilers. Several railroads have translated this interest into actuality in the shape of one or more locomotives; for example, the new high-pressure locomotives of the Delaware and Hudson (see Fig. 1 B) have nickel steel boilers. Others are still seriously considering it and experimenting. The same is true of manufacturers of large stationary boilers.

Previous Use—Unquestionably the Canadian Pacific railway independently pioneered in this development. It detracts in no way from them to say that inquiry has since developed that their action was anticipated more than a quarter of a century ago when the Baldwin Locomotive Works built a locomotive with boiler shell, firebox and other important parts of nickel steel. A few years earlier nickel steel plate had been employed for the tubes and boilers of the U. S. cruiser "Chicago." The first stationary boiler of nickel steel was also built about the same time. That these were not followed by more was probably because the demands were not as great then as now and a better plate was not necessary.

Ascertaining definitely that these boilers had been built so long ago settled quite as definitely the question of what life could be expected of nickel steel. The boilers of the "Chicago" are still in service after 30 years use, although the demands are now light. The same is true of the locomotive, which still operates after more than 25 years of service.

Comparison Of Nickel and Carbon Steel Plates

During the past two years, beginning with the plates rolled for the Canadian Pacific railway, data have been collected showing the physical characteristics of the low carbon 3 per cent nickel steel boiler plates. The averages of results of tests on all but a few nickel

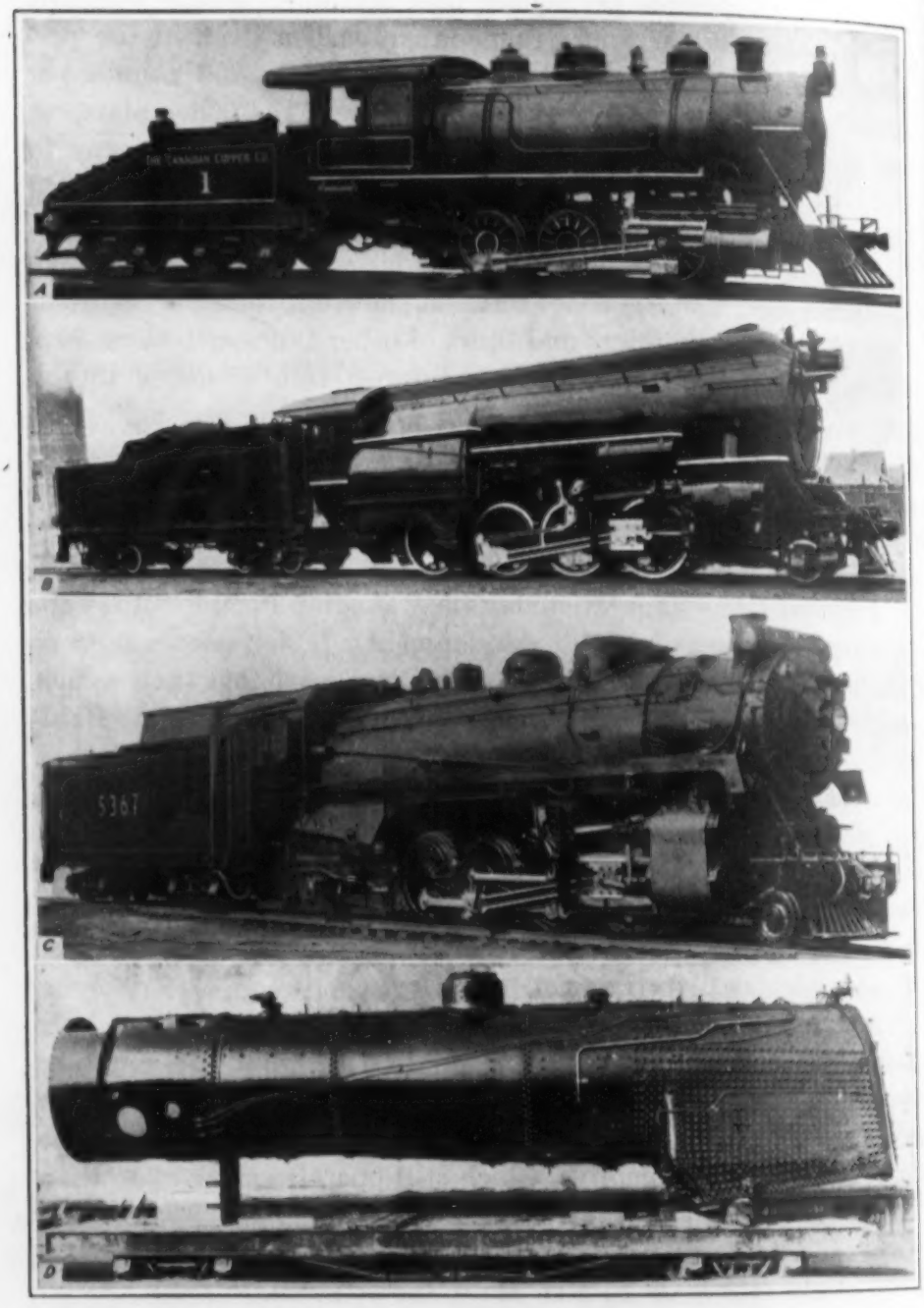

Fig. 1A—1904, First Locomotive Utilizing Nickel Steel for Boiler Construction. Built by Baldwin Locomotive Works. Boiler Shell, Firebox Sheets and Boiler Tubes of 3 Per Cent Nickel Steel. B—1928, Delaware & Hudson Railroad, High Pressure Locomotive, Nickel Steel Boiler Shell. Built by the American Locomotive Co. C—Canadian Pacific Railway, Mikado Type Locomotive, Nickel Steel Boiler Shell. Built by the Canadian Locomotive Co., Ltd. D—Canadian Pacific Railway Boiler with Nickel Steel Shell. Built by Montreal Locomotive Works, Ltd.

steel plates which have been utilized during this period for boiler construction are shown in the Table I and compared with an approximately equal number of tests on carbon steel boiler plate.

Table I
Average of 523 Tests on 3 Per Cent Nickel Steel Boiler Plate

	Average Per Cent	Specified		Average	Specified
Carbon	0.163	0.20 Max.	Ult. Tens. Str.	77,880 psi	70,000 Min.
Manganese	0.557	0.40-0.80	Yield Point	47,550 psi	50% U.T.S.
Phosphorus	0.021	0.045 Max.	Elongation in 8"	26.33%	1,600,000,Min.20%
Sulphur	0.029	0.045 Max.			U. T. S.
Silicon	0.203	Not. Spec.	Red. of Area	54.15%	50%
Nickel	2.960	2.75-3.25	Impact Value, Izod	63.4 ft. lbs.	

Table II
Average of 385 Tests on Carbon Steel Boiler Plate

	Average Per Cent		Average
Carbon	0.193	Ult. Tens. Str.	59,200 psi
Managanese	0.401	Yield Point	36,200 psi
Phosphorus	0.022	Elongation in 8"	28.64%
Sulphur	0.033	Reduction of Area	(Not determined)
		Impact, Izod	(Not determined)

Primarily nickel steel is used because of its higher strength with practically the same ductility as carbon steel. But, in addition, the other qualities which are desirable, even necessary, in a boiler are developed with nickel steel to a higher degree than with any other material, so that it is peculiarly, almost uniquely, suited to boiler requirements.

These additional qualities are its physical characteristics at high temperatures, its excellent impact values, its resistance to embrittlement in boiler service and its uniformity.

High Temperature Characteristics—Physical testing of boiler materials at room temperatures and under usual conditions can at best be only an approximate guide to the suitability of the material for boiler service. At best the working temperature of a boiler is some 200 degrees Fahr. higher in a temperature range where changes occur in the nature of the steel. But even worse, with the temperatures and pressures now being used, the steel enters the "blue-brittle" range, where an ordinarily soft and ductile metal

unaccountably loses its toughness and becomes very brittle, although the strength is greater than when cold. A piece of boiler steel which can be bent double when cold will break off short at this temperature and the fracture will have the characteristic blue color which alike indicates the temperature and the derivation of the term "blue-brittleness".[1]

A great deal of research into this matter of high temperature characteristics of steel has been done recently. The data most applicable here seem to be those incorporated in Figs. 2 and 3.[2],[3] The superiority at any temperature of the nickel steel over carbon steel is apparent. In Fig. 2 at 480 degrees Fahr. (corresponding to a saturated steam pressure of about 500 pounds per square inch gage) the properties of nickel steel are relatively low. Nevertheless there is a superiority over the special carbon boiler steel of 123 per cent in yield point, 7 per cent in tensile strength, 28 per cent in elongation and 8.5 per cent in impact resistance. The data embodied in this curve are taken directly from the authority quoted and the figures for carbon steel refer to a "special boiler steel" of German manufacture.

Embrittlement In Service—The high temperature characteristics of the metal are buttressed by another and unique feature. The boiler designer has always been faced by the specter of embrittlement in service. It has long been known that ordinary tensile tests are of little value as indices of performance in a boiler. Impact tests, resorted to as a means of detecting brittleness prior to service, have failed in their purpose. How misleading such tests can be is shown by the report of Goerens previously referred to. He discusses the phenomena of "aging" and "recrystallization" of boiler plate

[1]See "Tensile Properties of Boiler Plate at Elevated Temperatures"—H. J. French—*Transactions*, American Institute of Mining and Metallurgical Engineers, 1922, and discussion thereof.

[2]Data from "Die Kesselbaustoffe," by von P. Goerens, *Zeitschrift des Vereines Deutscher Ingenieures*, Jan. 19, 1924, Vol. 68, No. 3.

[3]The physical data presented in this paper should be considered comparable only in each given set of figures. This is particularly true of elongations and impact values, which vary widely according to the test specimen used.

In examining the results of several thousand tensile determinations, the author encountered discouraging discrepancies, due principally to varying conditions of test. The main factor causing discrepancies seemed to be the finishing temperature of the steel as rolled, which caused surprising variations of results. If this factor is disregarded, it is possible to obtain excellent tensile characteristics from a plate entirely unsuited for fabrication or subsequent service in a boiler.

In the work on nickel steel in our own and associated laboratories, the tensile test specimen was invariably the American Society for Testing Materials standard 8-inch plate specimen and the metal had been given the thermal treatment customary for this type of boiler steel; i. e., a retarded cooling after rolling.

in service and then gives interesting data on some full-size long-time tests. The data are too comprehensive and detailed to be included here, but in Fig. 4 are shown graphically the essential results. Briefly, he first annealed a carbon steel boiler plate (0.8 inch x 5.25 feet x 22.5 feet) and then formed it by bending as it would be

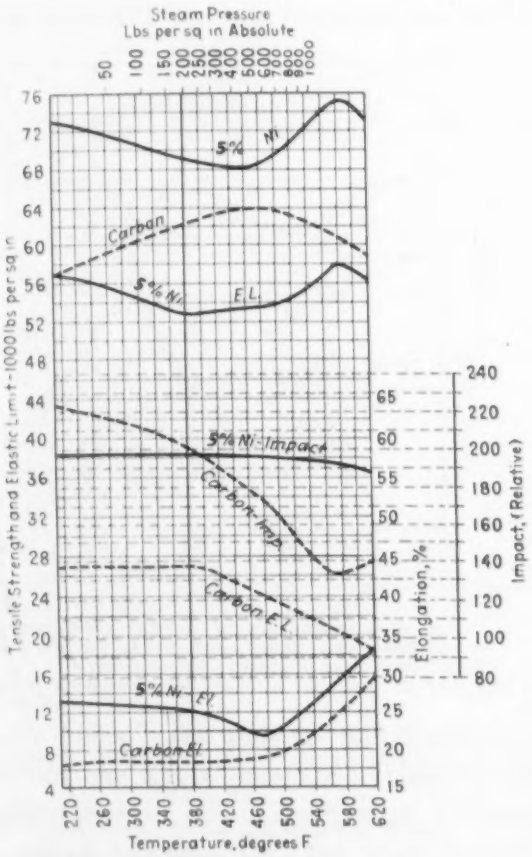

Fig. 2—Characteristic Curves of 5 Per Cent Nickel and Plain Carbon Steel Boiler Sheets at Elevated Temperatures.

formed in a boiler. Tested before bending and at intervals of 1 day, 1 year, 2½ years without actual service, and 2½ years with 17½ months in actual boiler service, it was found that the strength and elastic limit increased a little progressively while the elongation decreased after bending and then remained practically constant. But most striking is the serious dropping off in impact resistance, from 24.0 to 3.3, a decrease of 86.25 per cent. Small wonder that frequent inexplicable boiler failures occur through embrittlement and cracking.

In a similar way to aging, recrystallization affects boiler plate but not to so marked a degree. Fortunately, also, the effect of recrystallization is not markedly apparent until temperatures in excess of 900 degrees Fahr. are encountered. Practically, in a boiler the effects of either aging or recrystallization or both may occur because the plates are stressed during forming and bending in the

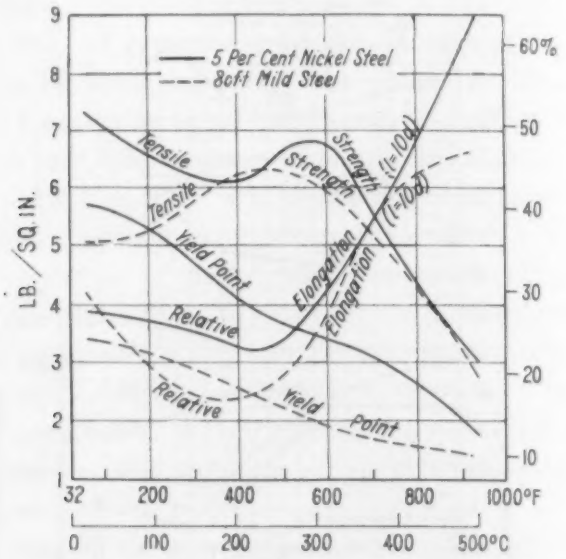

Fig. 3—Curves Showing Tensile Characteristics of 5 Per Cent Nickel and Plain Carbon Steel Boiler Sheets at Elevated Temperatures.

manufacture of the boiler or they may occur after the boiler is in commission as a result of stresses which are induced by differences in the temperature at various parts of the boiler. The injurious effects will become more noticeable as the boiler pressure and consequent thickness of the plates increase because of the greater difficulties of forming, bending and riveting heavier plate as well as because of the fact that increased heating surface and higher rates of evaporation offer more favorable conditions from temperature differences and additional stresses in the boiler.

Nickel steel resists these two destructive agencies to a marked degree, probably better than any other steel. The results of comparative aging and recrystallization tests on 5 per cent nickel steel and "special boiler steel" (carbon 0.11 per cent; manganese 0.53 per cent; phosphorus 0.026 per cent; sulphur 0.031 per cent) are embodied in Fig. 5 which shows conclusively the vast superiority of the nickel steel.

Uniformity—It is well known that there is marked variation both in the chemical composition and tensile results of test pieces taken at various parts of a carbon steel boiler plate[4] and that when specifications are met with tests from one place the plate may

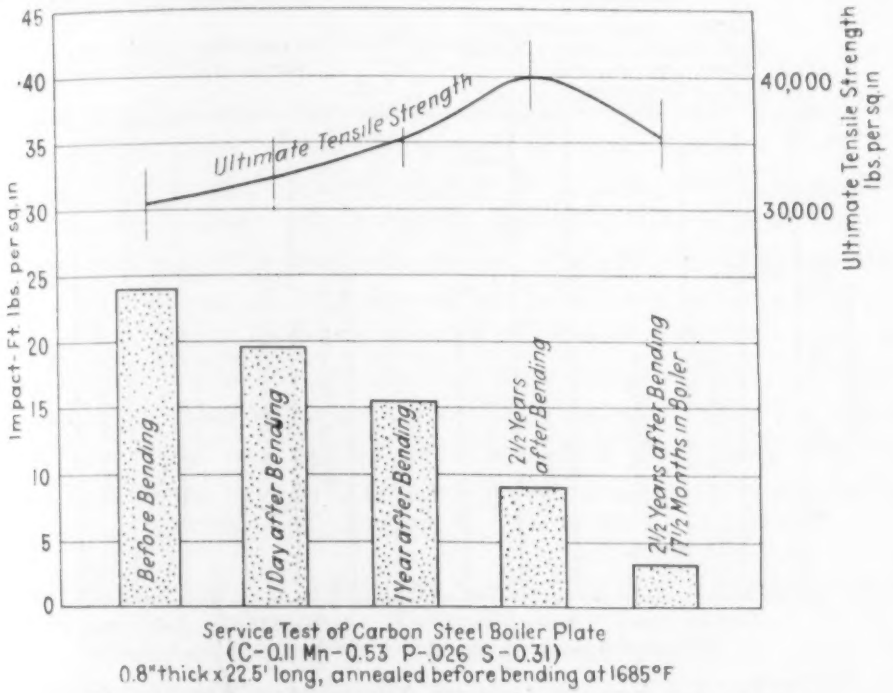
Ultimate Tensile Strength
Impact - Ft. lbs. per sq. in.
Ultimate Tensile Strength lbs. per sq. in.
40,000
30,000
Before Bending
1 Day after Bending
1 Year after Bending
2½ Years after Bending
2½ Years after Bending 17½ Months in Boiler
Service Test of Carbon Steel Boiler Plate
(C-0.11 Mn-0.53 P-026 S-0.31)
0.8" thick x 22.5' long, annealed before bending at 1685°F

Fig. 4—Graphical Representation of Data Obtained on Full-Size Long-Time Tests of Boiler Plate.

Table III
Uniformity of Tests on Nickel Steel

Analysis:	Carbon	Manganese	Phosphorus	Sulphur	Nickel
Per Cent	0.19	0.55	0.012	0.035	2.95

Test	Yield Point, Lbs. Per Sq. In.	Tensile Strength, Lbs. Per Sq. In.	Elongation, Per Cent	Area, Per Cent
Bottom Long.	40,600	77,800	25	56.1
Top Trans.	43,600	76,700	20	36.0
Bottom Long.	41,100	77,900	28	57.0
Top Trans.	42,200	77,700	25	48.9
Bottom Long.	43,500	78,400	25	58.2
Top. Trans.	43,100	78,600	25	49.1
Bottom Long.	42,100	77,400	26	59.7
Top Trans.	41,900	78,000	22.5	51.4
Av. Variation, %	2.86	2.70	2.37	11.4
Av. Variation, %, Carbon Steel, picked at random, same number	...	6.02	....	...

[4]See "Experiments on the Segregation of Steel Ingots in Its Relation to Plate Specifications"—C. L. Huston—*Proceedings*, American Society for Testing Materials, Vol. VI.

diverge dangerously from the requirements at other places. Experience has shown and it has often been commented on that one can confidently expect a much smaller variation with nickel steel. The

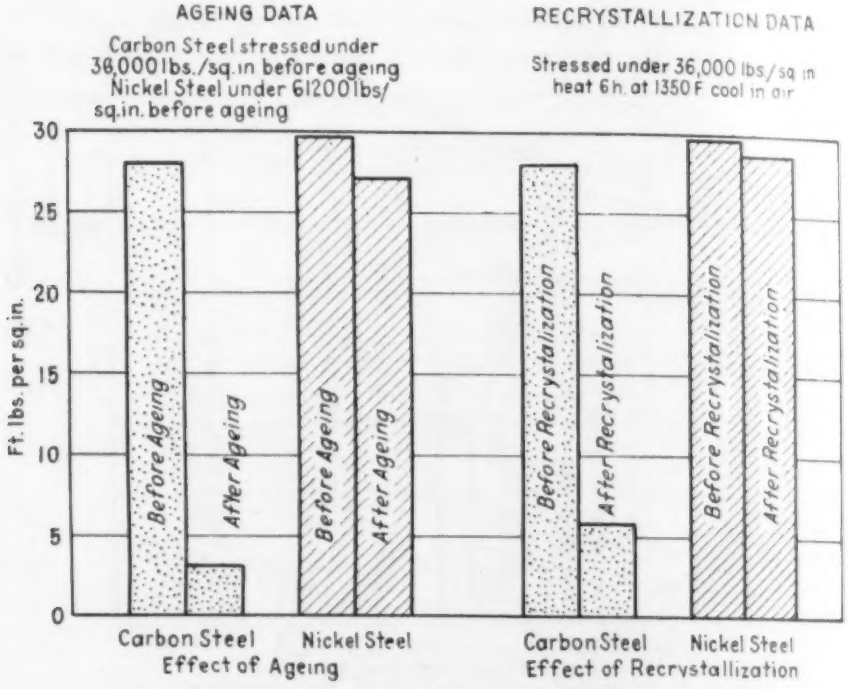

Fig. 5—Comparative Aging and Recrystallization Tests, on 5 Per Cent Nickel Steel and Special Boiler Steel Having the Following Analysis: Carbon 0.11 Per Cent, Manganese 0.53 Per Cent, Phosphorus 0.026 Per Cent, Sulphur 0.031 Per Cent.

Tables III and IV show the satisfactory results of several top and bottom tests, as well as the uniformity of analysis.

Bend Tests—This valuable test has been satisfactorily met. The specifications usually call for a top transverse bend test and, as a general rule, nickel steel not only meets the full requirements of an 180-degree bend about a pin whose diameter equals the plate

Table IV
Uniformity of Analyses on Nickel Steel

	Top			Bottom		
Carbon	0.29	0.22	Per Cent	0.21	0.15	Per Cent
Manganese	0.72	0.69		0.73	0.76	
Phosphorus	0.018	0.018		0.016	0.016	
Sulphur	0.021	0.024		0.027	0.023	
Silicon	0.25	0.25		0.23	0.22	
Nickel	2.62	2.68		2.66	2.66	

thickness, but can be closed down flat on itself without cracking. There is little difference between the bends on carbon steel and nickel steel. As a matter of fact, one user stated that the bend tests on nickel steel were the best he had ever seen.

Manufacture

Commercial Analyses—In the industrial application of nickel steels, consideration had to be given to the proportion of nickel to be used in the steel. It was eventually decided to use a 2.75 to 3.25 per cent nickel steel. The desirable characteristics of nickel steels are obtained with this steel, although to a slightly less degree than with 5 per cent nickel; the cost is less and there is the added advantage that such a steel is a standard of which many thousands of tons of plate have been made, the total eclipsing the aggregate amount of all other alloy steel plate ever rolled. Table V gives in abbreviated form the physical characteristics which have been obtained in tests of this steel and which are concordant with the results with 5 per cent nickel steel.

Table V
Properties of 3 Per Cent Nickel Steel

	Tensile Tests			Aging Tests		
	68° F.	480° F.	660° F.	Sample	After Aging	After Recrystallization
Ult. Tens. Str., Psi.....	62,200	64,000	54,100	62,300	66,900	60,000
Elastic Limit, Psi.....	42,700	28,500	25,600	42,700	59,700	38,000
Elongation, %	27.5	21.9	33.1	36.0	36.0	33.0
Red. of Area, %	71.0	63.0	73.1	71.0	67.0	70.0
Impact, Ft. Lbs.	30.6	29.8	28.4	30.1	27.7	29.0

The decision having been made to employ a 3 per cent nickel steel, there remained only to fit the steel to the boiler design. At that time a steel of 70,000 pounds per square inch minimum ultimate tensile strength was not only adequate, but generously so. A steel having between 0.15 and 0.20 per cent carbon was, therefore, decided upon and it has not been necessary thus far to depart from that standard.

Rolling—When the first plates were being rolled, it was mutually agreed by the consumer and the manufacturer that in order to take the most advantage of the contained alloy, the nickel steel

should be "killed",[5] although most boiler plate is not so treated.

With a killed steel, the yield is less than with the ordinary steel, on account of the piped portion of the ingot which must be discarded. A fair figure is 60 per cent or more usable product from the ingot. Also a killed steel is prone to have surface defects, such as "snakes" and "pits".

These variations in practice with killed steels, we submit, do not detract from their desirability but are, as a matter of fact, guarantees of superior quality. Killed steels for boiler plate have gained a great deal of favor recently and by some it is thought that for high-pressure work they will eventually supplant entirely the present type. They have one great advantage in that their defects are usually on the surface and apparent on inspection.

Nickel steel for plate is always killed in modern practice and therefore presents the same problems of yield and surface to the manufacturer. It is essential that the steel be well made, that approved ingot molds and hot-tops be used, that the heating of ingots prior to rolling be given careful attention and that the rolling itself be conducted so as to ensure the best possible surface. With these precautions, experience has shown that there is little difference between nickel steel plate and other killed steels, either in yield or in rejections on account of surface defects.

As a matter of fact, at least three of the largest users of nickel steel plate have recorded that the surface of nickel steel plate was equal to that of ordinary plate and one states that, disregarding entirely the alloy and compared on equal basis, the nickel steel plates furnished him were better plates than the carbon steel ones used at the same time and that during the construction of the boilers there were more rejections of carbon steel than of nickel steel.

Heat Treatment—One of the problems which was encountered and which had to be overcome by the manufacturer was that of unintentional heat treating of the nickel steel. Ordinary boiler plate is finished at the mill in a wide range of temperatures, depending largely on the thickness of the plate, and is straightened immediately after rolling. The continued passing of the plate back and forth between the leveling rolls has almost the same effect as a

[5] Briefly, a "killed" steel differs from an "open" or "rimming-in" steel in that sufficient silicon, manganese, aluminum or other element is added to render the steel substantially gas-free after solidification. A secondary effect is that, blowholes being no longer present in sufficient volume to counteract it, the steel exhibits piping along the center-line of the ingot. To lessen this, it is essential to use hot-tops and properly designed molds. Silicon is rarely in excess of 0.30 per cent in such steels.

quench. This does not make a great deal of difference on the low carbon steels but when nickel steel was so treated, the quick cooling hardened the plates considerably. It was found necessary to roll the plates at a temperature sufficient to ensure their finishing at a good red heat, after which the plates were rolled off the hotbed and piled one on top of the other and later covered with sand. Using this method it took the plates about eight hours to cool down to a black heat and this anneal, if it can so be termed, resulted in a better product and improved bend tests.

Fabrication—No difficulties in fabricating nickel steel plate have developed and no variation from standard practice has been necessary. Either carbon steel or nickel steel rivets can be used, as dictated by design and welding with the arc or gas process is perfectly feasible. Nickel steel welding rod should be used.

Possibility Of Higher Strengths With Nickel Steels

As was said earlier, the advantage of nickel steel is that of higher strength coupled with practically the same ductility and unusual impact-resisting powers. Since the development and use of this alloy steel for boilers, attempts have been made to achieve the same results without the use of nickel. We question the unqualified success of these endeavors.

There may be, in fact, there is to some extent now a demand for boiler plates of even higher strengths, say from 80,000 to 100,000 pounds per square inch. When such a demand exists, it can best be met with nickel steel. For the construction of the recently completed Delaware River bridge high tensile plate of two classes was required, one to meet a specified minimum elastic limit (yield point) of 45,000 pounds per square inch, and the other to show similarly 55,000 pounds per square inch. There was no limitation in the way these requirements were to be met. Any analysis, any carbon content, any alloying material could be used providing the steel met the required tensile specifications and bend test. For the 45,000 pounds per square inch steel, high tensile carbon steel was adopted but for the 55,000 pounds per square inch steel it was necessary to use nickel steel and none other was offered by any manufacturer. Several thousand tons were used. The average of 683 tests showed

a yield point of 62,690 pounds per square inch with an ultimate tensile strength of 104,750 pounds per square inch.[6]

This may be criticised on the ground that the plate was not for boilers. Reference then can be made to the boilers of the "Chicago", already mentioned. These plates of 3.5 per cent nickel steel had an ultimate tensile strength of 80,000 to 90,000 pounds per square inch, a yield point of 50,000 to 63,000 pounds per square inch with an elongation in 8 inches of over 20 per cent and they also met the full bend test.[7]

Table VI*
Corrosion Tests

(a) EXPOSURE CORROSION TESTS

	Loss in Weight, Lbs. Per Sq. Ft. Per Year	
	Sea Water	Fresh Water
Wrought Iron	0.1409	0.1275
Soft Steel	0.1612	0.1204
3.0 Per Cent Nickel Steel	0.1173	0.1021

(b) TWELVE MONTHS' EXPOSURE—SEA WATER

	Loss in Weight, Per Cent
Wrought Iron	1.89
0.25 Per Cent Carbon Steel	1.72
3.0 Per Cent Nickel Steel	1.36

(c) EXPOSURE TO STEAM AND SALT WATER

	Steam Two Months	Boiling Three Months 10 Per Cent NaCl Solution
	Loss in Weight, Per Cent	
Bessemer Steel	0.58	1.81
Open-Hearth Steel	0.33	1.98
3.0 Per Cent Nickel Steel	0.27	1.00

*Nickel Steel—Synopsis of Experiment and Opinion—D. B. Browne, *Transactions*, American Institute of Mining and Metallurgical Engineers.

The analysis of nickel steel now being extensively used for boilers was selected not because it was the ultimum obtainable, but because it meets the present requirements of strength adequately with excellent subsidiary characteristics. It now seems possible that the extension of some work already undertaken may make available another nickel steel as much superior to the present nickel steel as it is superior to carbon steel.

Corrosion and Firebox Cracks

While only a small consideration in the adoption of nickel steel

[6]Final Report, Board of Engineers, Delaware River Bridge Joint Commission.

[7]Private Communication, U. S. Navy. Also "Nickel Steel"—A. L. Colby, *Proceedings*, American Society for Testing Materials, Vol. III, 1903.

for boilers, a feature not to be overlooked is that of the increased resistance to corrosion. It is, of course, well known that above 20 per cent nickel confers practical immunity from the types of cor-

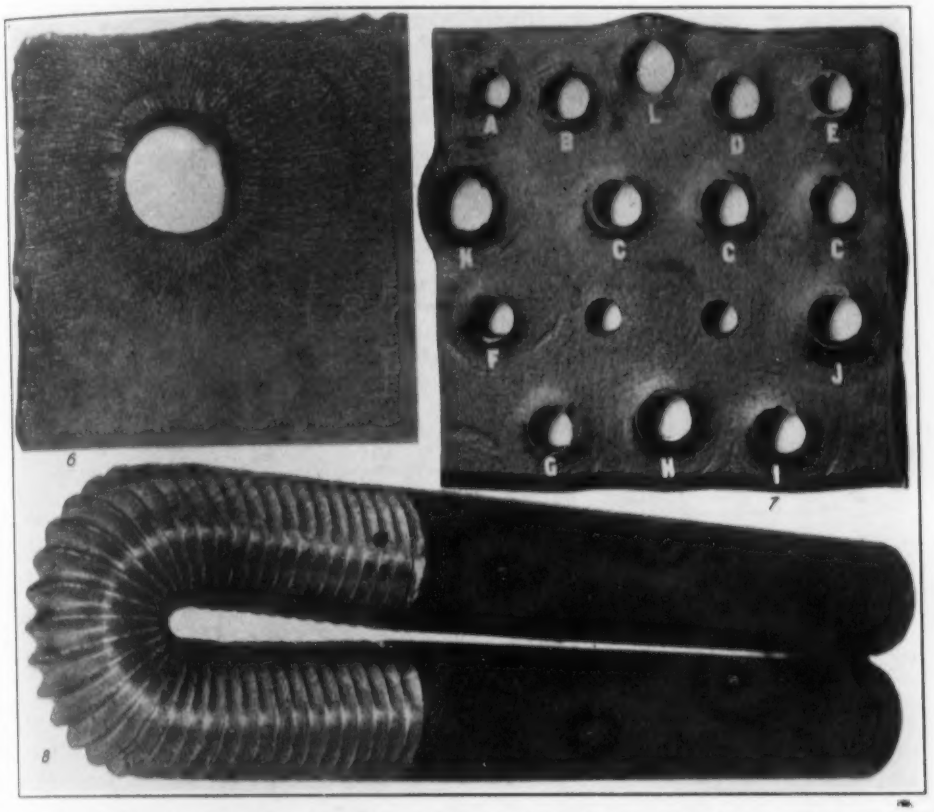

Fig. 6—Cracked Firebox Sheet Showing Corrosion Along Stress Lines. Fig. 7—Drift Tests on 100,000 Pounds Tensile Strength Nickel Steel Plate. Fig. 8—Bend Test on Threaded Nickel Steel Staybolt.

rosion met with in boilers and this immunity is proportional to the nickel content below that figure. With 3 per cent nickel, tests show a higher resistance to corrosion than the usual boiler materials.

There always has been trouble with firebox sheets of locomotive boilers cracking between the staybolt holes and this trouble is apparently increasing with the increase in the size of boilers and the pressures employed. It is usually considered that this cracking is fundamentally due to corrosion, but we feel that corrosion is of secondary importance. It is recognized that when a steel has been overstressed and then subjected to corrosive agents, the corrosion will take place more rapidly where the stress has occurred.[8] That

[8]See "Rissbildungen und Anfressungen an Dampfkesselelementen," Körber and Pomp, *Korrosion und Metallschutz*, May, 1927.

this condition exists in firebox sheets which crack seems to be demonstrated by the fact that even a superficial examination will show that the cracks running from one staybolt hole to another take on the appearance of magnetic lines of force (see Fig. 6); i.e. they follow the stress lines. We believe it unusual, if it occurs at all, for these cracks to run longitudinally or parallel with the direction

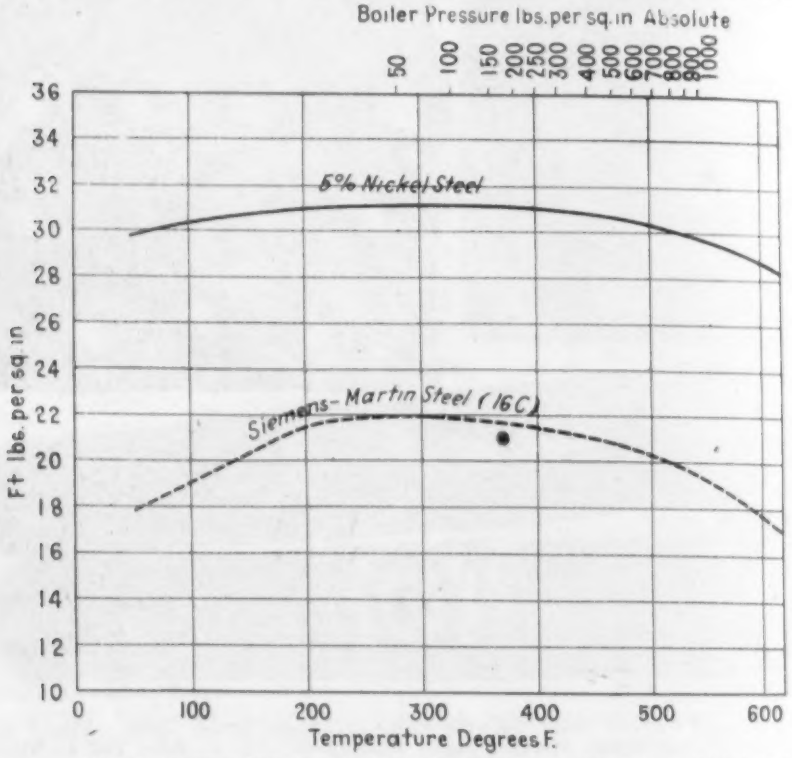

Fig. 9—Curves Showing Comparative Impact Resistance of Nickel and Carbon Boiler Steel at Elevated Temperatures.

of least strain in a firebox sheet. If these conclusions are justified, then it is not so much a question of corrosion as one of strength and resistance to embrittlement and the obvious remedy is to apply a stronger sheet. Nickel steel is of double advantage here as its higher strength and resistance to embrittlement enable it to resist the primary cause, while it is also naturally more resistant to corrosion. The first to make practical use of nickel steel for firebox sheets was the Canadian National railroad about three years ago and since then a number of others have made experimental installations. There has been no failure of nickel steel plate from this cause and, on the other hand, in the cases where it has been applied as a cure, it is reported as effective.

Boiler Tubes and Staybolts

For boiler tubes the situation regarding corrosion is exactly the reverse of that for shell plate as corrosion-resistance is here the primary consideration and the increased strength has little to do with it. Boiler tubes running from 0.10 to 0.20 per cent carbon and

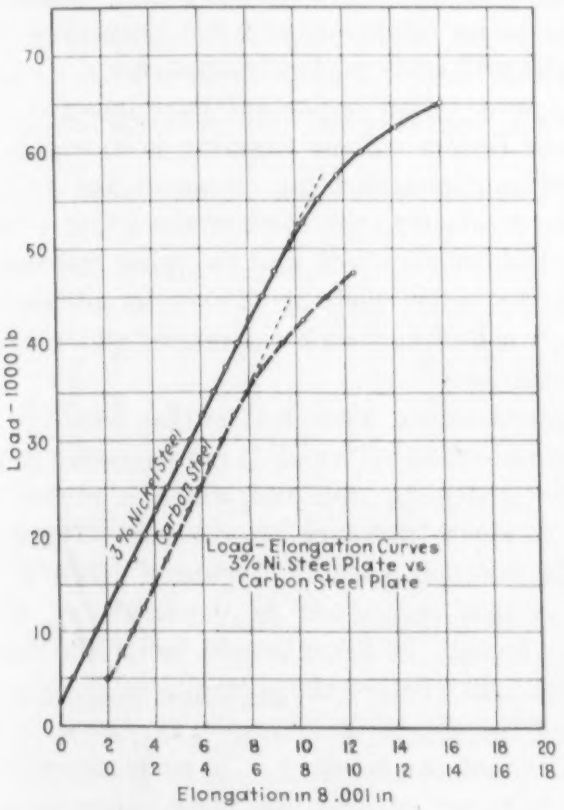

Fig. 10—Stress-Strain Diagram of 3 Per Cent Nickel and Carbon Steel Boiler Sheets.

containing about 2.0 per cent nickel have shown in actual service a life of from seven to fifteen times that of carbon steel tubes in districts where the water is bad. This, of course, has been sufficiently encouraging to warrant the extended use of nickel steel boiler tubes in bad water districts and in addition there are a large number of railroads who either have nickel steel boiler tubes under test or are using them as a regular material on some portions of their line. Their use is not entirely new, as tubes with a higher percentage of nickel were used by several of the navies, among them our own, as long ago as 1900, and ones with a lower nickel percentage only a

few years later. The unexplained peculiarity of these tubes has been the fact that boiler scale collects to a much less degree on them than on the ordinary tubes.[9] It has been reported in at least one case where a boiler was tubed partly with carbon steel and partly with nickel steel, the nickel steel tubes outlived three sets of carbon steel and when they were removed they were found to be in practically the same condition as when they came from the mill; that is, with the mill scale perfectly apparent.

Staybolts enter as an important part into the construction of certain types of boilers. Their function is to enable the firebox to resist the crushing and bursting pressure and to maintain it in proper relative position to the shell of the boiler. One end is fixed immovably in the firebox sheet, and the other end may also be fixed immovably in the boiler shell or it may be allowed some relative motion through a ball and socket joint, in which case it is known as a "flexible staybolt".

The primary load on a staybolt is that which it is designed to carry,—a pure tensile stress which is not excessive in relation to the strength of the materials used and which is numerically equal to the load due to steam pressure on a square of area equal to the product of the staybolt spacing distances. But a far more important load is that occasioned by expansion of the firebox and weaving of the boiler. In firing a cold boiler the firebox begins to expand longitudinally before the shell plates are hot, which results in a bending of the staybolts. Eventually, the shell is also heated and expands, so that the bending is to some degree recovered, but this recovery is never entirely complete, since there is always a marked temperature difference between the firebox sheet and the outside shell.

Furthermore, the inside of a boiler where it is in contact with hot gases is very sensitive to temperature changes. For example, the opening of the firebox door will almost instantly cause a contraction of the arch tubes and, to a lesser extent, the boiler tubes. With the closing of the door, expansion re-occurs. This movement is quite marked and has been measured. Any change in position of the in-

[9] "Non-Corrosive Nickel Steel Boiler Tubes"—A. L. Colby—*Proceedings*, Society of Naval Architects and Marine Engineers, Vol. 11, p. 135. Discussion elicited the fact that in a comparative test of two boilers, one tubed with ordinary tubes and the other with 3 per cent nickel steel tubes, after five months' service the nickel steel tubes were smooth, glossy and free from attached scale, while the ordinary tubes were rough and pitted, with scale covering the pitted surface. An 18 months' trial showed a 7 per cent fuel economy in favor of the boiler with nickel steel tubes.

side firebox is relative to the outer shell of the boiler and naturally, therefore, causes bending of the staybolts. In addition, the entire locomotive has a certain amount of vibration.

The result of all these factors is that the staybolts are subject to vibration and continual, even if slight, bending motion while under tensile stress, and ideal fatigue conditions are established.

Corrosion is also one of the important factors affecting staybolts. Located in the worst places in a boiler from a viewpoint of

Table VII
Comparison of Staybolt Materials

Material	Carbon	Manganese	Silicon	Nickel	Treatment	Yield Point, Pounds Per Square Inch	Tensile Strength, Pounds Per Square Inch	Elongation	Reduction of Area	Brinell Hardness No.	Impact	Endurance Limit	Stress to Cause Failure at 15,000 Cycles
Wrought Iron ...	0.02	0.04	0.13	...	As received	33,000	49,400	34.0	46.4	103	45	.....	.....
					1650 F. C.	30,300	46,500	36.5	49.3	95	32	.....	43,000
Wrought Iron ...	0.06	0.04	0.09	...	As received	34,000	48,600	34.8	51.2	102	46	31,000	48,000
					1650 F. C.	29,400	45,500	37.3	54.4	92	38	28,000	46,000
Staybolt Steel ..	0.06	0.02	0.01	...	As received	29,900	46,300	41.3	73.3	86	62	28,000	45,000
					1650 F. C.	19,300	49,700	41.0	69.3	88	17	27,000	44,000
Staybolt Steel ..	0.15	0.36	0.03	...	As received	32,250	58,800	39.5	65.2	110	69	30,000	49,000
					1650 F. C.	33,000	53,000	38.3	62.1	101	12	30,000	46,000
Staybolt Steel ..	0.18	0.47	0.07	...	As received	43,500	70,100	32.0	53.7	123	27	.....	.....
					1650 F. C.	34,100	63,800	32.0	51.1	112	9	31,000	49,000
Nickel Staybolt Steel	0.10	0.07	0.02	2.07	As received	39,600	53,000	41.8	72.7	104	87	.....	.....
					1650 F. C.	41,500	53,700	43.5	79.0	102	87	.....	53,000
Nickel Staybolt Steel	0.08	0.04	0.02	1.98	As received	40,700	54,900	40.0	76.9	107	82	35,000	.....
					1650 F. C.	42,700	55,100	43.8	77.0	103	83	32,000	51,000

corrosion and subjected to stresses and to a temperature difference between the ends, both of which induce chemical corrosion, the staybolt has always been peculiarly subject to rusting and pitting and one of the main considerations influencing the choice of material has been the ability to resist corrosion.

Steel has been replacing other materials used for staybolts quite rapidly and of the various compositions of steel used it is noteworthy that almost all contain nickel in amounts varying from 0.50 to 3.50 per cent. The analysis most often used is a very low carbon 2 per cent nickel steel. For staybolt service such a steel is superior to any other material as it is strong enough for the duty, yet remarkably ductile, has good resistance to fatigue and remarkable impact values. On tests this type of steel has consistently shown im-

pact values of such high order that no other steel is in the same class.

A comparison between staybolt material of wrought iron, steel and nickel steel is shown in Table VII.

Summary and Conclusions

As a material for boiler construction nickel steel offers the following advantages—

a. It is between 25 and 40 per cent stronger than carbon steel with practically the same toughness and greater resistance to impact.

b. At boiler temperatures it is much superior to carbon steel.

c. It is immune to aging embrittlement.

d. It is a commercial product and unusually uniform.

e. It can be made to develop even higher strengths than are now demanded.

f. It is resistant to boiler corrosion.

g. It is suited for use as boiler tubes and staybolts.

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DISCUSSION

Written Discussion: By W. G. Humpton, Lukens Steel Co., Coatesville, Pa.

The properties of nickel steel, as shown in this interesting and comprehensive paper, should merit its more extended use in locomotive boiler construction.

The reported favorable results on the performance of the boilers constructed some two years ago and the outline in the paper of the properties of such steel under temperature corrosion and what would in a sense approximate service conditions, would rather indicate that flue sheets, tube sheets, and crown and side sheets, which have been applied in the past year in locomotive construction would likewise show excellent performance.

There have been quite a number of instances of rather short life in service of carbon steel plates when used in the above mentioned parts of locomotives. This is true. Where the materials have met, in all respects, the chemical and physical limitations as laid down in the specification, but for some unaccountable reasons have not suitably withstood the service conditions. Flue sheets in particular have been the source of considerable trouble, and in the majority of cases crack in the knuckle of the flange, a location subjected to a breathing action brought about by temperature changes, and no doubt with such stresses there is an accompanying corrosion process.

It will be interesting to follow up these more recent applications of nickel steel in order to ascertain its value in withstanding such service conditions.

Written Discussion: By W. A. Newman, Canadian Pacific Railway Co., Montreal.

The information given in Mr. McKnight's paper is certainly very comprehensive. When I compare the data that have been presented with what I was able to secure when the Canadian Pacific Railway Company was first considering the use of alloy boiler steel, I must confess that the information available at that time appears very meager.

You will no doubt be interested to know that not only has our nickel boiler steel proved satisfactory but experiments that we have been conducting over a considerable length of time with locomotive forging steels and staybolt steels indicate that nickel forging steel of very much the same chemical composition as that given for nickel boiler plate appears to be most desirable for our requirements. Our experiments originally started with various types of alloy steels having a carbon content between 0.35 and 0.50 per cent. We have found, however, that it is distinctly beneficial to decrease the carbon and at present we are working to a physical specification requiring a minimum of 55,000 pounds per square inch yield point, 30 per cent elongation and 50 per cent reduction of area, this for straight normalizing treatment.

Our experiments with staybolt steels have been somewhat similar. Our present specification calls for a maximum carbon content of 0.10 per cent. What we require in locomotive work is materials of maximum toughness and ductility that will withstand the maximum abuse and misuse, or, in other words, a foolproof material. It is rather remarkable just what abuse our very low carbon 2 per cent nickel steel staybolts will stand, in fact, the steel will not harden under the severest treatment.

I have frequently been asked just why we are inclined to favor nickel steels for boiler plate and other uses and in thinking over what best describes their quality, I think the phrase "bulldog toughness" most aptly describes their characteristics. They are not only tough and ductile at ordinary temperatures but they "hang on" to these properties over a wide range of conditions and temperatures.

I would suggest that you endeavor to get Mr. McKnight to give you some additional information in the future in regard to other uses for nickel steel as I am sure you will find some of the information that I know he has, will be of just as much interest as what he has already presented in connection with nickel steel boiler plate.

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

THE CONSTITUTION OF STEEL AND CAST IRON
SECTION II—PART III

By F. T. Sisco

Abstract

This installment, the third of the present series continues the discussion of annealing. It deals specifically with the structural changes taking place in annealing plain carbon steels, and in those two important phases of heat treatment, normalizing and spheroidizing. The structural changes taking place are discussed from the standpoint of equilibrium conditions, and the resulting structure is described and illustrated.

IN the previous installment we discussed in a general way the three factors entering into the process of annealing, namely:—heating to the proper temperature, holding at this temperature for the proper time, and cooling from the annealing temperature down to normal. We viewed the structural changes taking place during each of these steps and the effect on the structure of such variables as changing the rate of heating and cooling, the time of holding at the annealing temperature and the like.

With this discussion as the groundwork we are now prepared to examine the actual structural changes taking place in annealing steels of various carbon percentages. We are also prepared to take up some of the variations in thermal treatment that are customarily grouped under the general term annealing,—for example, normalizing, spheroidizing, etc.,—and discover, if possible, what happens in these processes and why. The important subject of annealing

This is the thirteenth installment of this series of articles by F. T. Sisco. The several installments which have already appeared in TRANSACTIONS are as follows: June, July, August, September, November, 1926; January, February, April, June, August, October, 1927; February, 1928.

The author, F. T. Sisco, is Chief of the Metallurgical Laboratories, U. S. Air Corps, War Department, Wright Field, Dayton, Ohio.

below the critical range, especially of cold drawn wire; and some of the more important miscellaneous annealing operations,—annealing alloy steels, steel castings, patenting, and the graphitization of malleable iron will, in the next installment, conclude our discussion of annealing.

In talking over the various phases of annealing we will attempt to confine our discussion to the theoretical considerations involved. We are not going to describe how the man at the fire or the man at the furnace treats his steel when he anneals, or normalizes, or spheroidizes it; almost every one knows that now. What we want to do is to try to describe what goes on inside the bar of steel, or the casting, or the piece of wire when it is annealed, normalized or spheroidized. In annealing we know the effects pretty well, so we can be chiefly concerned with the causes. We will try to follow the causes by understanding what effect heat has on the metallographic structure, and how this change in structure can be correlated with properties: in other words we wish to tie up our theoretical causes with the known and easily observed effects.

In our discussion we will, in so far as it is possible without going too deep, treat the structural changes on the basis of equilibrium. In common with many other things, steel that is unnaturally strained from some operation or other is in an unstable structural condition; we say that it is in a condition of unstable equilibrium and is held in this state by its rigidity. In general, annealing is an operation which, by the application of heat, imparts sufficient mobility to the material so that there is a structural change from an unnatural or unstable state to one that is natural or stable. We have stressed equilibrium conditions in all of our past discussion of the constitution of the iron-carbon alloys; in heat treating operations a conception of it and its accompanying structural manifestations becomes of outstanding importance.

Structural Changes in Annealing Plain Carbon Steels

A normal hypoeutectoid steel containing between 0.05 and approximately 0.80 per cent carbon is, as we know, an aggregate of pearlite and free ferrite. We are familiar, of course, with the fact that the lower the carbon, the greater the amount of free ferrite. When hypoeutectoid steel is heated uniformly there will be no structural change until the lower critical point, Ac_1, is reached. At

this point, as we have already learned, the eutectoid pearlite is changed to austenite, also of eutectoid composition. As heating is continued the austenite gradually absorbs the free ferrite which has undergone allotropic transformation to the gamma modification. When the Ac_3 point has been passed, the absorption of the gamma iron is complete and we have a homogeneous solid solution of carbon or iron carbide in gamma iron or austenite, with a carbon content equal to that in the original steel.

When this steel is cooled from the annealing temperature the free ferrite is rejected by the austenite as the material cools from the Ar_3 to the Ar_1 point, until, at this latter temperature, the remaining austenite is of eutectoid composition. In cooling through the temperature range between Ar_3 and Ar_1, the gamma iron changes to the alpha modification. If cooling is sufficiently retarded the rejection of the excess ferrite by the austenite is complete.

With very slow cooling the free ferrite has the opportunity to form distinct grains as is evident in Fig. 19. When cooling is not quite so retarded the ferrite rejection by the austenite will be complete but insufficient time is available for this excess constituent to collect into individual grains. In this case we have a resulting structure similar to that shown in Fig. 20, in which part of the ferrite has been rejected to the grain boundaries; the rest is distinguishable as white patches of varying size remaining within the pearlite grains. When cooling is still more accelerated only a part of the free ferrite which was rejected by the austenite is in a form that can be distinguished by the microscope. This is shown in Fig. 21 where a relatively small amount of the excess ferrite has been rejected to the grain boundaries. The rest is emulsified and is contained within the pearlite (in this case finely granular) grains. Still more accelerated cooling results in a condition similar to that shown in Fig. 22. We are sure that there is free ferrite present, we can see traces of it in the microstructure, but there are no distinct grains of it evident, nor are there any grain boundaries where it has segregated. When cooling is so accelerated that it produces a condition similar to that shown in Fig. 22 we can almost say that we have a sorbitic structure instead of a pearlitic one and free ferrite.

These four photographs show, by means of the structural condition and appearance of the free ferrite in hypoeutectoid steels,

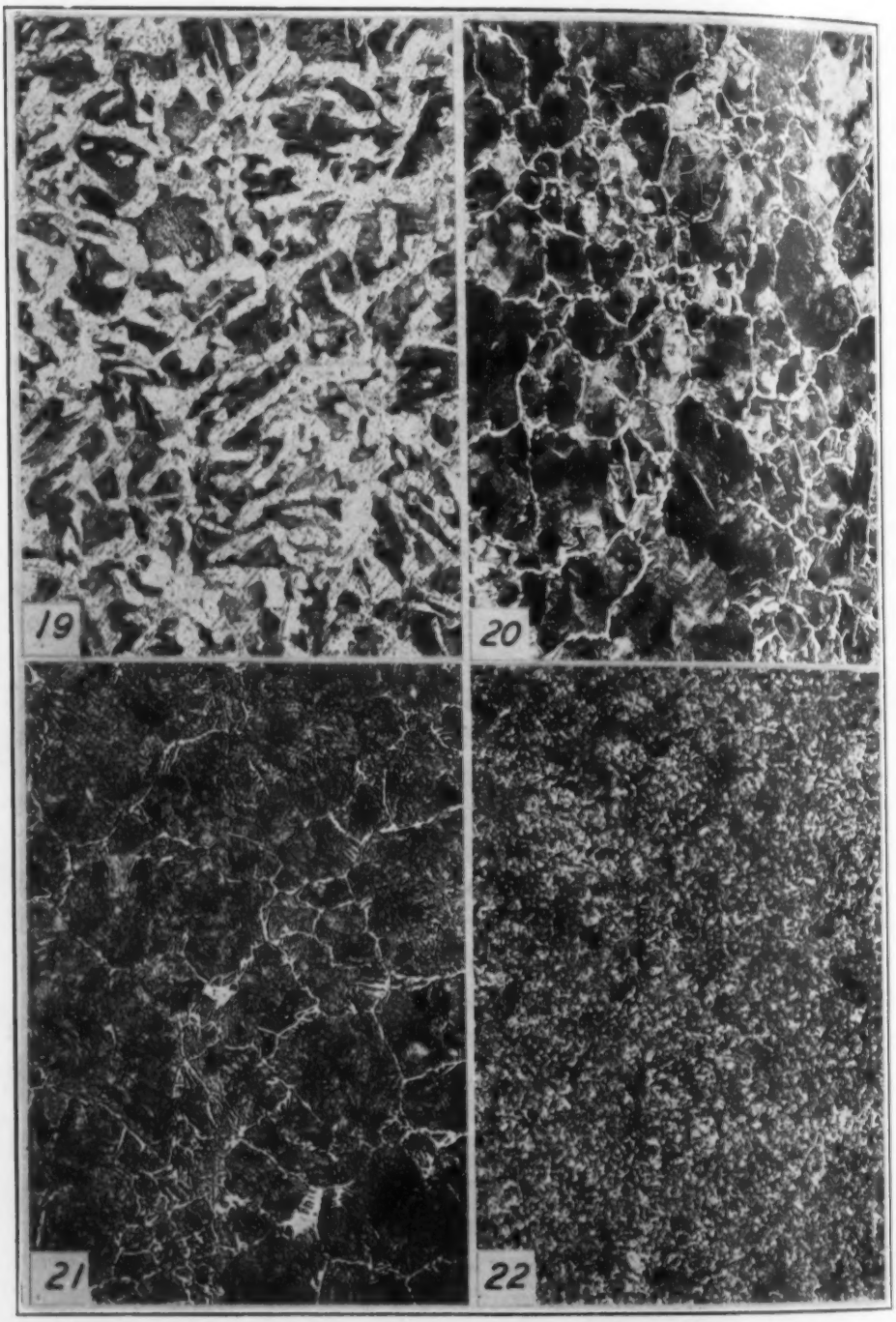


Fig. 19—Photomicrograph of 0.40 Per Cent Carbon Steel. Ferrite Completely Segregated Into Distinct Grains. Fig. 20—Photomicrograph of 0.45 Per Cent Carbon Steel. Ferrite Partly Rejected to the Grain Boundaries and Partly Segregated in the Pearlite Grains. Fig. 21—Photomicrograph of 0.45 Per Cent Carbon Steel. Part of the Ferrite Rejected to the Grain Boundaries. The Rest of the Ferrite is Emulsified in the Pearlite Grains. Fig. 22—Photomicrograph of 0.40 Per Cent Carbon Steel. No Ferrite Segregation Apparent, No Grain Boundaries Evident. These Four Photomicrographs Are of Annealed Carbon Steel Cooled at Different Rates. All Specimens Etched in Alcoholic Nitric Acid. All Magnifications 100 X.

the effect of varying the cooling rate from the annealing temperature. The condition shown in Fig. 19 is the nearest approach to stable equilibrium, the structure of Fig. 22 is typical of almost unstable equilibrium; it borders closely on sorbite, which is usually considered as one of the constituents in hardened (or hardened and tempered) steels. In addition to the structural changes in the

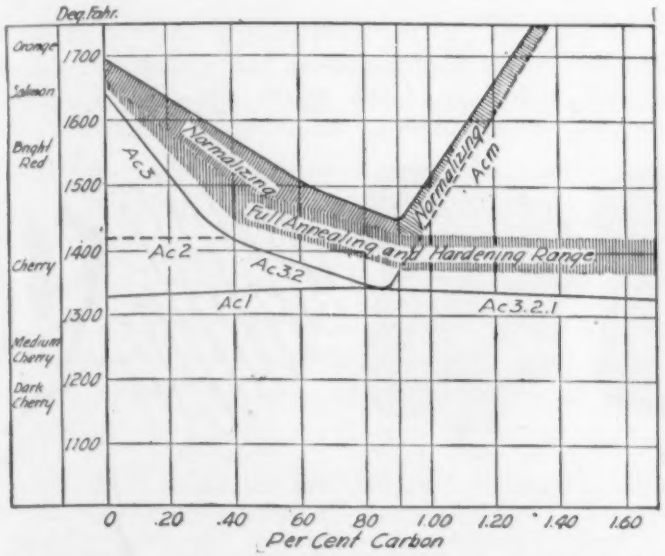


Fig. 23—Iron-Carbon Diagram Showing Heat Treatment Ranges.

ferrite, the cooling also affects the condition of the pearlite. We had occasion to refer to this in the previous installment, but will illustrate it further here in describing the structural changes in eutectoid steels.

In the case of normal eutectoid steels (0.80 to 0.90 per cent carbon), at atmospheric temperature there is only one constituent present, pearlite. Heating these steels above the Ac_{3-2-1} point results in the change of this pearlite to the solid solution austenite, also of eutectoid composition. When steel is cooled slowly, at Ar_{3-2-1}, pearlite is again formed. Any detectable differences in structure after annealing will be due to differences in the appearance of this constituent. As was described and illustrated in the previous installment, very slow cooling results in the familiar laminated pearlite, thin parallel plates of cementite and ferrite; or it may even result in a partial breaking up or balling up of the cementite which gives a structure known as divorced pearlite. More rapid cooling results in a pearlite in which the laminations may be curly, or so fine that they are hardly recognizable at all. This latter form

is, as we have seen, known as granular pearlite. Still more rapid cooling may result in a very fine emulsified structure in which the laminations cannot be resolved by the microscope at all and in which there is little or no free ferrite evident even at high magnification. This structure is known as sorbite and is classed more properly under the constituents in hardened and tempered steel.

Fig. 24 by Arnold[21] shows graphically the structure and properties of pearlite. The first phase is the granular, almost sorbitic pearlite resulting from relatively fast cooling, the second and third

Phase I Phase II Phase III Phase IV

Fig. 24—Properties and Kinds of Pearlite. Fe_3C Represented in Black. (*After Arnold as Published by Sauveur.*)

Phase I—Sorbitic Pearlite with Emulsified Fe_3C. Very Dark on Etching. Maximum Tensile Strength 150,000 Pounds Per Square Inch. Elongation 10 Per Cent.
Phase II—Normal Pearlite with Semi-Segregated Fe_3C. Dark on Etching. Maximum Tensile Strength 120,000 Pounds Per Square Inch. Elongation 15 Per Cent.
Phase III—Laminated Pearlite with Completely Segregated Fe_3C Exhibiting a Play of Gorgeous Colors When Lightly Etched. Maximum Tensile Strength 77,000 Pounds Per Square Inch. Elongation 5 Per Cent.
Phase IV—Laminated Pearlite Passing Into Massive Fe_3C and Ferrite. Maximum Tensile Strength 66,000 Pounds Per Square Inch.

phases are the normal pearlite so frequently encountered in our micrographs and resulting from slow cooling[22]. The fourth phase is the result of very slow cooling and is a structure bordering on divorced pearlite.

In Fig. 24, the fourth phase is the nearest approach of pearlite to a condition of stable equilibrium. The second and third phases, although much more common in our photomicrographs of annealed high carbon steels, picture a structural condition not quite so stable as that in the fourth phase; and the first phase, granular pearlite, is the least stable of all.

When steels contain more than 0.90 per cent carbon excess cementite makes its appearance in the microstructure. Consider-

[21]From Sauveur, Metallography and Heat Treatment of Iron and Steel, 1926, page 209.

[22]These structures are illustrated in the previous installment, Figs. 13 to 17, inclusive, TRANSACTIONS, American Society for Steel Treating, February, 1928, pages 313, 315.

able of this constituent must be present before it can be distinguished readily by the microscope. A steel containing 1.20 per cent carbon contains only 5.4 per cent excess cementite. Annealing high carbon steels containing 0.90 to 1.30 per cent carbon at the customary temperatures affects only the pearlite. A 1.20 per cent carbon steel cooled slowly from hot working temperatures will, at normal temperatures, consist of 5.4 per cent excess cementite and 94.6 per cent pearlite. If we heat this steel slowly and uniformly no structural change will occur until the Ac_{3-2-1} point is reached. At this temperature the pearlite will change to austenite of eutectoid composition. Now if we cool slowly through the Ar_{3-2-1} point this austenite will again change to pearlite; divorced, laminated, or granular, depending upon the rate of cooling. In this regular annealing process consisting of heating into the annealing range shown in Fig. 23 (reproduced from part II, Fig. 11) the excess cementite is not affected. In other words annealing a 1.20 per cent carbon steel is exactly like annealing an eutectoid steel and affects only the pearlite. It sometimes is very desirable, in fact necessary, to change the structural condition of the excess cementite. This is accomplished by the operation of normalizing.

Structural Changes in Normalizing

In a former installment[23] we traced the constitutional changes in a high carbon steel containing 1.25 per cent carbon that occurred in cooling from above the melting point to atmospheric temperature. When this steel solidified it consisted of the solid solution austenite containing 1.25 per cent carbon, which is equivalent to 6.2 per cent excess cementite, and 93.8 per cent pearlite. This austenite containing 1.25 per cent carbon cooled unchanged until the Ar_{cm} point was reached—for this steel about 1725 degrees Fahr. At this point the austenite became supersaturated with respect to cementite, and as a result some of this constituent was rejected by the solid solution. This rejection continued as the temperature fell from the Ar_{cm} point to the Ar_{3-2-1} point, at which temperature the remaining austenite was of eutectoid composition. (see Fig. 23)

If cooling is slow the excess cementite will be rejected to the grain boundaries and will take the form of a network around the pearlite grains. Some cementite will not reach the grain boundaries

[23] Transactions, American Society for Steel Treating, November, 1926, page 804.

and will be found as needles or spines within the grains. Two such typical structures are shown in Figs. 25 and 26. In Fig. 25 only a small amount of cementite is present. At a magnification of 500 diameters a little can be detected at the grain boundaries, the rest appears as white needles within the grains. In Fig. 26 at 100 diameters, the cementite network around the grains is distinct and fairly heavy and there is considerable of this hard constituent located within the grains.

When a high carbon steel is heated to the annealing temperature, about 1400 degrees Fahr. (760 degrees Cent.), free cementite is, as we have already stated, unaffected. Consequently, although we have refined the structure of the pearlite matrix, we have not secured a thoroughly soft and ductile steel due to these needles and envelopes of hard, brittle cementite that enclose the pearlite grains. In order to break up this network of free cementite we must heat the steel to a temperature sufficiently high so that this constituent will go into solution in the austenite. This is shown in Fig. 23, which gives the normalizing temperatures for the high carbon steels as a range of about 50 degrees Fahr. above the Ac_{cm} line.

After heating to this high temperature to affect the solution of the excess cementite we must now cool sufficiently fast so that it will remain in solution. If we allowed the steel to cool slowly the excess cementite would be again rejected by the austenite and would again form a network around the pearlite grains. Consequently we accelerate the cooling by quenching in air or oil. In the case of high carbon steels we can ordinarily obtain our objective by cooling in air.

We can now define normalizing as a process of heating hypereutectoid steels to a temperature high enough to affect solution of the excess cementite, followed by cooling relatively fast so that most of the excess cementite will be retained in solution at atmospheric temperature.

In order to attain our objective in breaking up the network of hard, brittle cementite we have practically undone two of the most important results of annealing. We have first of all heated our steel to such a high temperature (100 to 300 degrees above the $A_{3\text{-}2\text{-}1}$ point) that considerable, often an excessive grain growth takes place. Secondly we have cooled the material so rapidly that some hardening generally takes place, thus making machining diffi-

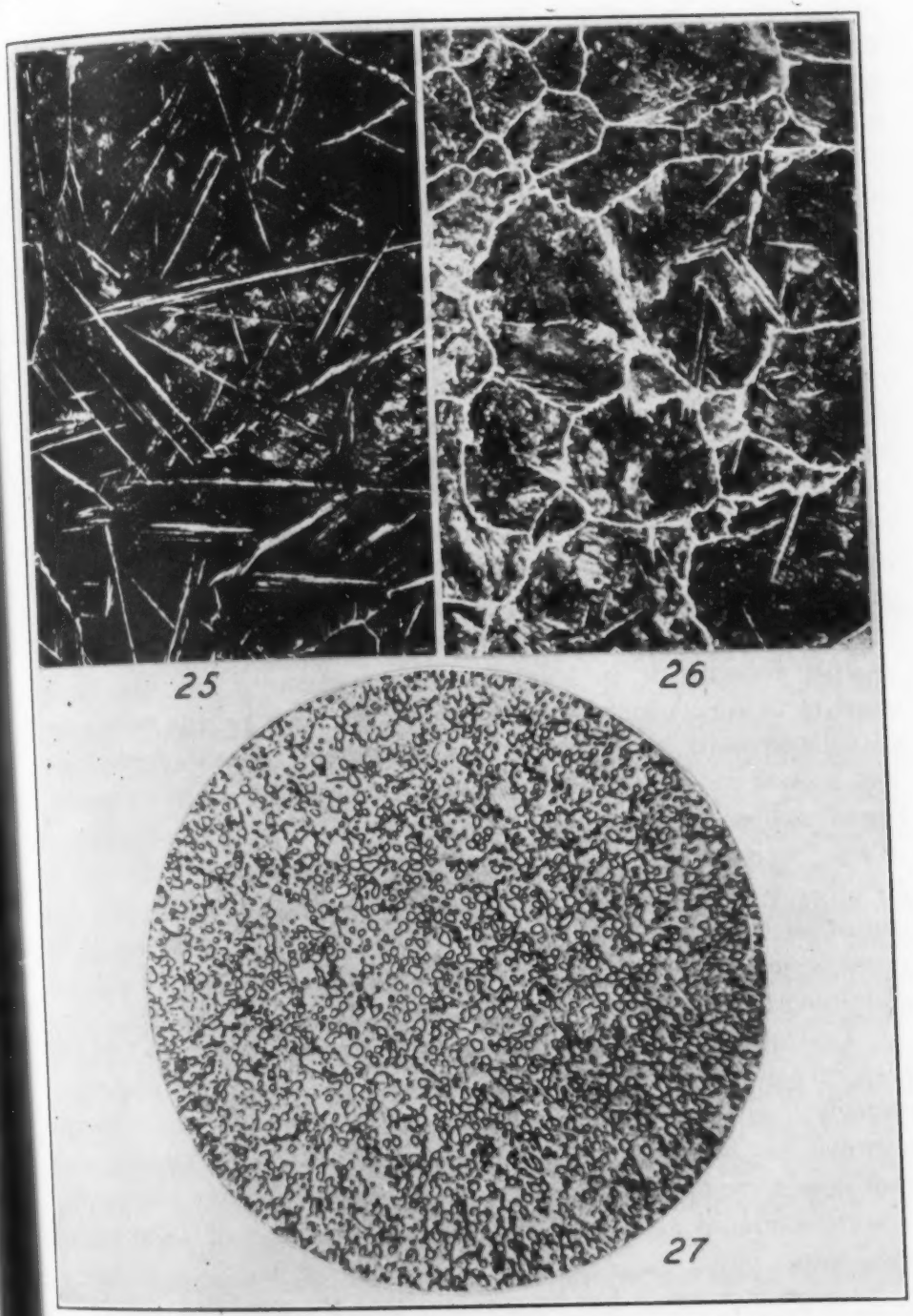


Fig. 25—Photomicrograph of 1.10 Per Cent Carbon Steel. Pearlite Grains Dark. Cementite Appearing as a Network and as Needles in the Grains. Magnification 500 X. Fig. 26—Photomicrograph of 1.40 Per Cent Carbon Steel. Cementite Network Around the Grains and Massive Cementite in the Grains. Mag. 100 X. Fig. 27—Photomicrograph of 1.25 Per Cent Carbon Steel. Mag. 100 X. Cementite and Spheroidized Completely. All Specimens Etched in Alcoholic Nitric Acid.

cult. Hence, in order to have a desirable, homogeneous structure, one that is soft and ductile, and still have a minimum of the hard, brittle network or needles of free cementite present, we must follow our normalizing by an annealing treatment. If we anneal by heating just above the Ac_{3-2-1} point we replace the large grains by desirable small grains and we change our hard sorbite or troosto-sorbite into soft and more ductile pearlite.

Coming back to equilibrium conditions, let us see what happens in normalizing. If we cool a high carbon steel slowly from rolling or forging temperatures, we have laminated pearlite with excess cementite in the grains and at the grain boundries. We have a condition approaching stable equilibrium. Now if we heat this steel to ordinary annealing temperatures and cool slowly we have practically the same structure as we had before, with the possible exception of a change in grain size, laminated pearlite and free cementite. We have not changed our conditions of equilibrium greatly. Now if we heat this steel high enough to effect the solution of the excess cementite and cool rapidly enough to keep most of this constituent in solution, we have cooled too rapidly for pearlite to form; instead we have sorbite, or even the harder constituent troostite. The steel is now much more unstable structurally. But now if we anneal this steel by heating to the proper annealing range and cooling slowly we have a return to stable equilibrium (or at least a condition approaching it) with our pearlite again evident. In other words normalizing and annealing has resulted in a final condition of stable equilibrium but has changed the form of the excess cementite from a hard, brittle network to smaller and well distributed particles.

One of the greatest advantages of normalizing, especially for high carbon tool steels, is that it improves the hardening properties; more uniform and thorough hardening results when the cementite network has been thoroughly broken up. Steels containing much free cementite should always be normalized and the normalizing operation should always be followed by some sort of an annealing operation.

In recent years it has been found that the most desirable structural condition for machining and for hardening high carbon tool steels (and for some alloy steels as well) results from normalizing followed by annealing at a temperature at or just below the Ac_{3-2-1}

point. This operation is known as spheroidizing and will be discussed presently.

Although normalizing temperatures are generally sufficiently high so that considerable grain growth may occur, this treatment also equalizes the grain size and for that reason is occasionally used in low and medium carbon steels. In many hot working operations, especially in forging and hammering, finishing temperatures may be high. If this is the case very large grains will be the result. Often hot working leaves the piece extremely heterogeneous in structure. Heating to the normalizing range shown in Fig. 23, holding at this temperature until saturated, followed by relatively rapid cooling will make the structure uniform. The normalizing treatment is frequently used for steels of 0.40 to 0.75 per cent carbon.

Structural Changes in Spheroidizing

Spheroidizing may be defined as an annealing treatment carried out by heating to the lower critical point or just below this point. The object of spheroidizing is to produce a structural condition whereby the cementite is in the form of rounded particles or spheroids, instead of lamellae as is the case in ordinary annealing. In general, spheroidizing increases the machinability and toughness of the steel and in many cases makes it respond better to hardening. In most cases spheroidizing follows the normalizing treatment.

In all of our previous discussion of the iron-carbon alloys we have stressed the fact that if conditions are favorable the alloy tends to seek a condition of stable equilibrium. In the case of steels slowly cooled from above the critical range this stable condition is usually evidenced by distinct grains of laminated pearlite and excess ferrite or cementite as the case may be. When we studied the cast iron series containing more than 1.70 per cent carbon we saw that the cementite, instead of partly forming pearlite and partly appearing as an excess constituent, tends to dissociate into iron and free carbon (graphite), the final stable form.

If conditions could be made ideal—infinitely slow cooling for example—theoretically we would find that graphite and not cementite was the final stable form even in the low carbon alloys. Practically however, very slow cooling of the low carbon alloys, (the steel series containing less than about 1.70 per cent carbon)

results in laminated pearlite and excess ferrite or cementite. In our previous discussion we have considered laminated or divorced pearlite to be stable, and in truth it is, because it is what we always get in our commercial slow cooling.

We have learned also that there are several structural varieties of pearlite, ranging from the emulsified or granular pearlite, the result of relatively rapid cooling, to the pearlite of large distinct laminations, the result of very slow cooling. If cooling is still more retarded which is sometimes possible in very large sections, we see a tendency for further approach to a condition bordering on stable equilibrium, namely the divorce of the cementite and its collection into rounded, often large particles.

Laminated pearlite, the result of our customary annealing process for steel is often not just the structural condition we desire. We want to produce a condition still more stable, in other words we want a structural condition whereby the cementite is in rounded particles instead of long, narrow plates. We have found that steel in this structural condition often has higher strength and elastic limit, higher ductility and softness, especially marked in high carbon steels. In addition it seems to machine better and respond more uniformly to hardening.

It might be possible to secure this condition by a regulation of the cooling, but it is hardly practicable. So instead of trying to regulate our regular annealing process to produce the spheroidization of the cementite we cause it by a more complicated treatment, but one much more easily controlled.

In order to produce this spheroidized cementite in high carbon steels where it is a most valuable structural condition, we first of all normalize, thus breaking up the brittle cementite network and producing a matrix of granular pearlite, sorbite or even a more unstable form. Then we reheat the steel to a temperature just at or just below the Ac_{3-2-1} point. At this heat there is a distinct mobility and a marked tendency for the cementite to assume the rounded, spherical form.

To a certain degree, the more unstable the structural condition, the more rapid and complete the stabilization tendency upon reheating, and the more complete the resulting spheroidization. If the steel is sorbitic it spheroidizes readily. Fine lamellar pearlite spheroidizes more quickly and more completely than pearlite with

coarse lamellae. The result is that we get a better and more complete spheroidization if a high carbon steel has been air-cooled from the normalizing temperature than if it is cooled very slowly.

It has been found that hypereutectoid steel spheroidizes most readily, hypoeutectoid steel probably ranks next, and eutectoid steel last. The reason for this is that the excess cementite or ferrite acts as a nucleus for the spheroidization process. There are many factors entering into spheroidization. The structural condition of the steel—that is, whether it is sorbite, granular or laminated pearlite—is of utmost importance. Very important also, is the temperature to which the steel is heated and the length of time the steel is held at this temperature.

In spheroidizing high carbon steels they are usually normalized first to break up the cementite network. This is done by heating to the temperature shown in Fig. 23, followed by air or oil quenching. The steel is then reheated to about 1275 to 1350 degrees Fahr. and held long enough to produce the required structure. This of course varies with the composition of the steel, its structural condition and the properties desired.

For spheroidizing hypoeutectoid steels, they are heated to a temperature just at or slightly below the Ac_1 point followed by air cooling. They are usually normalized; that is, annealed or oil-quenched before spheroidizing.

Emmons found by experiment that a completely spheroidized steel is not always the best for machining. He recommends regulating the annealing process, especially the cooling so that the resulting structure consists of about 25 per cent lamellar pearlite and the balance spheroidized cementite and carbonless iron.

Fig. 27 shows a 1.25 per cent carbon steel in which the cementite has been completely spheroidized.

Lonealing is a term coined[24] to cover the operation of annealing below the critical range followed by any rate of cooling. It can be differentiated from spheroidizing first, in that the latter may involve heating to some point just within the range as well as just below the range, and second, in spheroidizing the material is held for a relatively long time at the proper temperature and in addition cooled slowly in the upper part of the cooling range. Lonealing defines a general class of annealing operations (for example annealing

[24]Recommended definitions, TRANSACTIONS, American Society for Steel Treating, Vol. 5, page 251.

after cold work etc.) while spheroidizing defines a specific treatment.

We will see in a later installment, that spheroidizing resembles tempering in many respects. In fact it is often hard to differentiate the two. Tempering is an operation that involves reheating a hardened steel to some temperature below the critical range with the object of relieving strains, reducing the hardness and brittleness and increasing the toughness and resistance to shock. Many times a high carbon steel air-cooled or oil-quenched in normalizing is hard. If that is the case, reheating to, or just below the critical point is, in fact, tempering in that it does relieve strains and reduce the hardness. But it is more than that; it is a definite operation to which the steel is subjected with the object of attaining a definite structural condition, while tempering is a general class of operations with different objectives.

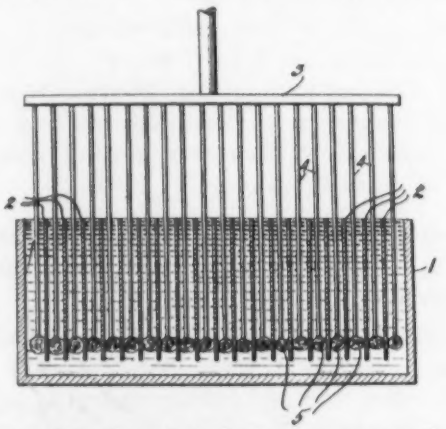
Spheroidizing is used almost universally for some high carbon steels, and especially for some alloy steels. Many of the alloy steels cannot be machined satisfactorily nor hardened uniformly unless they are spheroidized. This is especially true of the steels that contain excess cementite and other carbides. We will have occasion to look further at this in the next installment.

Reviews of Recent Patents

By NELSON LITTELL, Patent Attorney
475 Fifth Ave., New York City—Member of A. S. S. T.

1,654,716, Rust-Proofing Process, William H. Allen, of Detroit.

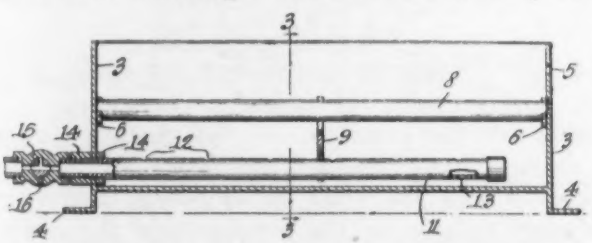
This patent relates to the process of rust-proofing, particularly applicable to sheets and other articles which are subsequently to be enamelled. It is an object of the invention to prevent the sheets from becoming roughened by the coating of phosphate of iron which is deposited in the rust-proofing process. In the drawing, the tank 1 indicates a solution of water phosphoric acid and iron filings which is first boiled and the



sheets 2 to be coated with the phosphate are suspended therein by means of a suitable rack. A frame 3 above the tank 1 is provided with a series of rods 4 carrying at their lower ends rolls or pads 5 of cotton cloth or other suitable material. During the rust-proofing process, the frame 3, supporting the pads 5, is moved slowly up and down to lightly rub the surfaces of the sheets 2 to prevent crystalline growth thereon and preserve the smoothness of the sheets.

1,654,954, Tub, Claude C. Westerman, of Bremen, Ohio.

This patent describes a quenching tank, particularly for the tempering of steel bits in which the edge of the bit is held in position to receive



a steady flow of cold water thereon. The tank comprises a trough 1, supported upon the ends 3, in which is located the inlet pipe 11 for the

cooling fluid and the supporting racks 8 which hold the drills in position to receive the flow of water against the edge thereof. The racks 8 and the pipe 11 can be readily disconnected and removed, exposing the interior of the tub for cleaning operations.

1,659,214, Metal-Treating Compound and Method of Making Same, Milton L. Moyer, of Souderton, Pennsylvania, Assignor, by Direct and Mesne Assignments, to Milton L. Moyer, Edwin J. Prindle, and Bradley Stoughton, Joint Trustees.

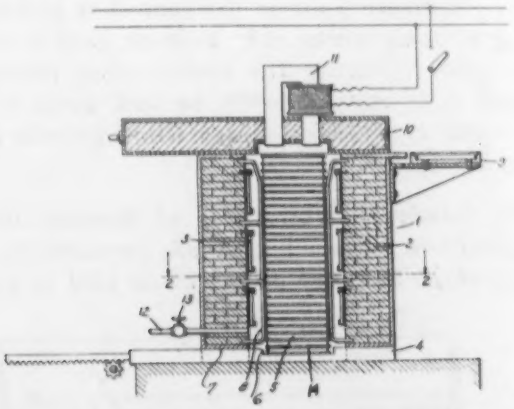
This patent describes a metal treating compound consisting of

soap, eight ounces
sperm oil, two ounces
alum, one-half ounce
mercury bichloride, one-quarter ounce
zinc sulfate, one-quarter ounce
litharge, one-eighth to one-quarter ounce
carbon, one-eighth to one-quarter ounce.

The iron and steel articles undergoing treatment are first heated to a straw color and then immersed in the compound and left preferably until thoroughly cool. This patent describes several comparative tests indicating the benefits of this compound.

1,659,550, Method of and Furnace for Uniting Metal Parts by Fusion, Christian Steenstrup, of Schenectady, New York, Assignor to General Electric Co., a Corporation of New York.

This invention relates to an apparatus for automatically uniting metal parts by fusion and comprises a towerlike furnace 1 heated by suitable resistors 3, closed at either end by sliding, charging and removing doors 4 and 10, means being provided at 12 for introducing a non-oxidizing gas,

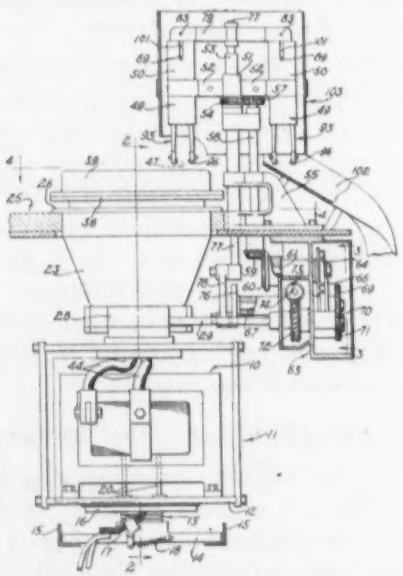


such as hydrogen, into the chamber. In the operation of the device, the articles to be charged in the furnace for fusion are placed one at a time upon the support 9 and the slide 10 is moved thereover, the electromagnet 11 energized to pick up the articles from the support 9 and carry them in position over the stack 5 inside the furnace. The current to the electromagnet 11 is then shut off and the article dropped to the top of the

pile. As the articles reach the bottom of the pile, the slide 4 is actuated by the rack and pinion to move the lowermost article below the shoulder 6 of the slide outside the furnace where it can be removed and the slide 4 returned in position below the stack for the reception of the next article.

1,659,946, Apparatus for Heat Treating Articles, Joseph William Fay, of Villa Park, Illinois, Assignor to Western Electric Co., Incorporated, of New York, a Corporation of New York.

This invention describes an apparatus for automatically heat treating articles in which the articles 47 undergoing treatment are supported in an electrical heating element enclosed within the chamber 38 and 39, which heating element rotates in a horizontal plane, the heat being supplied from



suitable conductors to the brushes 17 which contact with concentric rings 16 below the transformer casing 10. The transformer casing 10, as well as the heating elements within the chamber 38 and 39, are constantly rotated from the worm 73 and worm wheel 72. At the completion of each revolution of the articles 47 placed in the heating elements inside the chamber 38 and 39, these articles are brought opposite the fingers 93 of a revolving turret 50 and the fingers actuated to grasp the articles and remove the same from the furnace and on rotation of the turret 50 through 180 degrees release the heat treated articles and permit them to drop through the chute at 102.

1,659,661, Steel Alloy and Process of Making the Same, Thomas A. Moormann, of Milwaukee, Assignor to Kinite Corp., of Milwaukee, a Corporation of Wisconsin.

This patent describes a new steel alloy having a composition approximately of carbon 1.50 per cent, chromium 13 per cent, cobalt 0.70 per cent, molybdenum 1.10 per cent, boron 0.05 to 0.20 per cent. It is an object of the inventor to produce an alloy for steel casting in which the film of

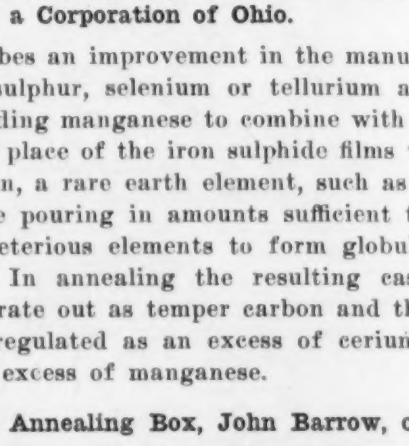
oxide which forms on the ordinary steel casting alloy and which adheres during the pouring of the casting so as to carry with it entrained sand and other extraneous matter resulting in imperfections in the surface of the casting is eliminated, resulting in a smooth surface steel casting. Another advantage resulting from this alloy is that the size of the risers necessary to obtain solid castings may be greatly reduced. This result is accomplished by the use of a relatively small quantity of boron which, in chromium alloys, forms a very fluid flux which has no deleterious effect on the surface of the castings. The boron is added shortly before tapping the furnace in the form of ferroboron or boron manganese.

1,660,398, Manufacture of Malleable Cast Iron, Harry A. Schwartz, of Cleveland Heights, Ohio, Assignor to National Malleable and Steel Castings Co., of Cleveland, a Corporation of Ohio.

This patent describes an improvement in the manufacture of malleable cast iron containing sulphur, selenium or tellurium above certain limits, whereby instead of adding manganese to combine with the sulphur to form manganese sulphide in place of the iron sulphide films which interfere with the annealing operation, a rare earth element, such as cerium, is added to the molten iron before pouring in amounts sufficient to combine with the sulphur and other deleterious elements to form globules rather than iron sulphide net work. In annealing the resulting casting, the combined carbon is free to separate out as temper carbon and the amount of cerium does not need to be regulated as an excess of cerium does not have the harmful effects of an excess of manganese.

1,660,702, Welded Annealing Box, John Barrow, of Columbiana, Ohio.

This patent describes a welded annealing box which is so constructed that no weld will occur at the corners or other points of stress. The box comprises a main body or plate 10 constituting the top 11 and the two sides 12 of the box, the sides joining the main plate 10 by curved portions



13. The plate 10 and the sides 12 are inwardly flanged at 14 to define the rectangular opening 15 into which the plates 16 are welded to the flange portions 14. The flange portions extending past the corners and below the top of the box receive the strains which normally occur at the corners, thereby protecting the weld around the edges of the plate 16 and increasing the life of the box.

THE ENGINEERING INDEX

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Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each month with a specially prepared section of The Engineering Index. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the copy prepared for the annual volume of the Index published by the A. S. M. E.

In the preparation of the Index by the staff of the A. S. M. E. some 1,200 domestic and foreign technical publications received by the Engineering Societies Library (New York) are regularly searched for articles giving the results of the world's most recent engineering and scientific research, thought, and experience. From this wealth of material the A. S. S. T. will be supplied with a selective index to those articles which deal particularly with steel treating and related subjects.

Photostatic copies (white printing on a black background) of any of the articles listed may be secured through the A. S. S. T. The price of each print, up to 11 by 14 inches in size, is 25 cents. Remittances should accompany orders. A separate print is required for each page of the larger periodicals, but whenever possible two pages will be photographed together on the same print. When ordering prints, identify the article by quoting from the Index item: (1) Title of article; (2) name of periodical in which it appeared; (3) volume, number, and date of publication of periodical; and (4) page numbers.

AIRPLANES

MANUFACTURE. The Works of the Bristol Aeroplane Company. Automobile Engr., vol. 18, no. 238, Feb. 1928, pp. 46-53, 16 figs. Special production methods of Bristol Aeroplane Co. to insure accuracy and high-grade finish; foundry equipped for production of aluminum castings; in machine shop plant machines are grouped almost entirely according to type; machining heavy duralumin crankcase; using separate operation drawings in shop wherever possible; white metal for bearing bushes centrifugally cast; protection of finished parts against rust and corrosion.

ALLOY STEELS

COPPER CONDITIONS. Anti-Corrosive Steels Containing Copper (Les aciers inoxyadables au cuivre), Technique Moderne, vol. 20, no. 3, Feb. 1, 1928, p. 146. Describes series of alloy steels developed in France under trade name of Apso; these steels are not absolutely stainless, such as those having high nickel and chromium content, but they are considerably less expensive, extremely resistant to atmospheric conditions and to sulphuric acid and hydrochloric acid solutions.

MANUFACTURE AND PROPERTIES. Alloy Steels, Their Manufacture, Properties, and Uses, H. C. H. Carpenter. Royal Soc. Arts—Jl., vol. 76, nos. 3923 and 3924, Jan. 27 and Feb. 3, 1928, pp. 250-271 and 278-297, 17 figs. Jan. 27: Describes two methods of classifying nickel steel; information is presented in graphic and tabular form, and photomicrographs are included showing structure of steel; statistics of production; principal alloying metals used; effect of alloying metals on inversions of steels. Feb. 3: Tungsten, chromium and manganese steels; manufacture; properties and uses.

PROGRESS. The Steel and Alloy Steel Industry During 1927, S. J. Hewitt. Indus. Chemist, vol. 4, no. 36, Jan. 1928, pp. 18-19, 2 figs. Demand for alloy steel for automobiles and general engineering having been well maintained; in reference to these industries, steels containing small percentage of molybdenum, in addition to chrome and nickel, are coming into more general use; introduction of Ajax Northrup high frequency electric furnace by Electric Furnaces Co. Ltd., to replace crucible furnace for manufacture of alloy tool steels has been outstanding feature of 1927.

ALLOYS

ANTI-CORROSIVE. Corrosion Resistant Alloys. Mech. World, vol. 83, nos. 2142 and 2143, Jan. 20 and 27, 1928, pp. 48-49 and 64. Presence of electrolytes in solution most important external factor causing corrosion; corrosive attack increased with concentration until it reaches critical concentration, then decreases until limiting concentration reached; iron-silicon; iron-chromium; chromium-nickel-iron and nonferrous alloys; copper alloys present interesting peculiarities as regards corrosion; improve corrosion-resisting qualities of copper alloys by substituting nickel; Everdur. Corrosion-resistant properties of different alloys; choice of alloy.

HEAT RESISTING. Heat Resisting Alloys, T. H. Turner. Metal Industry (Lond.), vol. 32, no. 6, Feb. 10, 1928, pp. 153-155, 4 figs. Properties required in heat-resisting alloys; how demand for resistance to high temperatures has been met; main groups of heat resisting alloys; choice of particular alloy; alloys for steam use. Abridged report

Those members who are making a practice of clipping items for filing in their own filing system may obtain extra copies of the Engineering Index pages gratis by addressing their request to the society headquarters, whereby their names will be placed on a mailing list to receive extra copies regularly.

of lecture given before co-ordinated Societies in Birmingham, Eng. (To to concluded.)

MAGNETIC. Magnetic Alloys Names and Defined. Iron Age, vol. 121, no. 8, p. 534. Several important brands in common use described in terms of properties and composition; permalloy; hipernick; copernick; A metal; thermalloy; K. S. magnetic steel, cobaltcrom; permanite and nomag.

NICKEL-GOLD-PALLADIUM. The Alloys of Nickel, Gold and Palladium, W. Fraenkel and A. Stern. Metallurgist (supp. to Engineer), Jan. 27, 1928, pp. 14-15, 2 figs. Study of liquidus surface of nickel-gold-palladium alloys; binary system formed by three metals; gold-nickel alloys solidify in similar manner to nickel-palladium group, minimum occurring between 15 and 20 per cent of nickel; as all three binary systems give rise to complete series of solid solutions, it is probable that ternary system will, in neighborhood of solidus, also consist of single series of solid solutions. Abstract translated from German.

TEMPERATURE, EFFECT OF. On the Influence of Temperature on the Properties of Alloys, J. Cournot. Information on Refrigeration (Institut Int. du Froid)—Monthly Bul., no. 9-10, Sept.—Oct. and Oct.—Nov. 1927, pp. 873-874. Author summarizes present state of knowledge on variation of properties of alloys and practical consequences therefrom; study of these variations is made by means of test tubes of alloys considered, by bringing these tubes to temperatures required and determining by appropriate tests values of properties sought for. Translated from Rev. Scient., no. 19, 1927, pp. 589-595.

ALUMINUM

RECRYSTALLIZATION. Tensile Strength and Electric Conductivity of Recrystallized Aluminum Wire and Its Practical Application for Rolling Process. (Zugfestigkeit und elektrische Leitfaehigkeit an rekristallisiertem Aluminiumdraht und die Nutzanwendung fuer den Walzvorgang), H. Bohner. Zeit. fuer Metallkunde, vol. 20, no. 1, Jan. 1928, pp. 8-13, 6 figs. Review of literature on recrystallization of aluminum; relation between tensile strength and electric conductivity and influence of chemical composition on these properties; results of tests on pure aluminum of different composition and application of results to manufacture of aluminum wire.

ALUMINUM ALLOYS

CASTINGS. Influence of Soda Additions on the Strength of Aluminum-Copper Alloys (Sand-Cast Aluminum) [Ueber den Einfluss von Natriumzuschlaegen auf die Festigkeitseigenschaften von Aluminium-Kupfer-Legierungen (Aluminium-Gusslegierungen)], F. Goederitz. Giesserei, vol. 15, nos. 3 and 4, Jan. 20 and 27, 1928, pp. 55-61 and 82-88, 23 figs. Investigates influence of different soda additions on strength, elongation, notch strength, hardness and grain size of aluminum-copper alloys 96:4, 92:8, 80:20 and 68:32; it is shown that sodium in general has deteriorating effect on all mechanical properties; includes photomicrographs.

CONSTITUTION. The Constitution of Alloys of Aluminum with Silicon and Iron, A. G. C. Gwyer and H. W. L. Phillips. Engineering, vol. 125, nos. 3239 and 3240, Feb. 10 and 17, 1928, pp. 179-182 and 210-212, 21 figs. Investigates conditions and limits of composition determining appearance of various constituents, with view to elucidating any structural changes taking place during ordinary operations of working and annealing. Paper read before Inst. of Metals, Abridged.

LAUTAL. The Experimental Determination of the Curve of Critical Dispersion of Lautal (Die experimentelle Bestimmung der Kurve der kritischen Dispersion der Legierung Lautal), K. L. Meissner. Zeit. fuer Metallkunde, vol. 20, no. 1, Jan. 1928, pp. 16-18, 10 figs. Aging tests on Lautal specimens were undertaken at aging temperature of 125 to 220 deg. Cent. in order to obtain curve of critical dispersion of Lautal; critical aging temperature was found to be about 160 deg. Cent.

PROPERTIES AND TREATMENT. Production and Industrial Applications of Aluminum Alloys (Die technische Herstellung und Verwendung von Aluminium-Legierungen), v. Zeerleder. Schweizerische Bauzeitung, vol. 91, no. 3, Jan. 21, 1928, pp. 27-30, 8 figs. World's aluminum production for period of 1903 to 1927 and statistics of aluminum exported from Switzerland for period of 1907 to 1927; chemical composition and mechanical properties of duralumin, anticorodal and other aluminum alloys; improving aluminum alloys by heat treatment and other methods; uses of aluminum alloys in electrical transmission.

ALUMINUM BRONZE

CASTING. Casting Large Bronze Ingots, J. Strauss. Metal Industry (Lond.), vol. 32, no. 6, Feb. 10, 1928, pp. 160-162. Commercial ingots of aluminum bronze generally weight 200 to 500 lb., according to dimensions of bars or sheets required; how they are melted and poured; methods of machining and forging; effect of forging and annealing temperatures on physical properties of aluminum bronze; properties of ingots. Abstracted from Iron Age, Dec. 8, 1927. (To be concluded.)

BEARING METALS

LEAD-BASE. A Discussion of Lead-Base Bearing Metal, G. A. Nelson. Western Machy. Wld., vol. 19, no. 1, Jan. 1928, pp. 12 and 25, 3 figs. As substitute for tin-base babbitt metal at much lower price; use in line shaftings and parts of machines that do not receive shocks; heated to 1000 deg. Fahr.; at definite intervals of time, temperature readings taken; time plotted against temperature; care to prevent segregation in pouring box of this metal; use of tin bearing for lower half of box and lead bearing for upper half.

BEARINGS

MANUFACTURE. The Manufacture of Ball and Roller Bearing, G. James. Iron and Steel of Canada, vol. 11, no. 2, Feb. 1928, pp. 37-44, 22 figs. Outline of major operations; initial forming methods of steel balls; furnace for hardening balls; rough hard grinding or lapping; final grinding; polishing and surface inspection; gaging; forming, annealing and machining bearing rings. Paper read before Eng. Inst. of Can.

BERYLLIUM

PROPERTIES. Beryllium—Lighter than Aluminum, R. E. Kirk. Minn. Techno-Log, vol. 8, no. 4, Jan. 1928, pp. 109-110 and 122. Properties of beryllium and advantages; hard enough to scratch glass, malleable, of high tensile strength, better conductor of electricity than copper; history; occurrence; alkali-fusion and fluoride-fusion methods of extraction from ores; chemical and electrolytic reduction methods; extended use awaits production at reasonable price.

PROPERTIES. Alloys of Beryllium with Copper, Nickel, Cobalt and Iron (Legierungen des Berylliums mit Kupfer, Nickel, Kobalt und Eisen), G. Masing. Zeit. fuer Metallkunde, vol. 20, no. 1, Jan. 1928, pp. 19-21, 2 figs. Investigations on behavior of beryllium with above named metals; discusses technical properties of alloys and their machinability.

BERYLLIUM ALLOYS

BERYLLIUM-COPPER. Refining of Beryllium-Copper Alloys (Vergueetungserscheinungen bei Beryllium-Kupferlegierungen), O. Dahl. Zeit. fuer Metallkunde, vol. 20, no. 1, Jan. 1928, pp. 22-24, 5 figs. Shows dependence of refining process on beryllium content of alloys and annealing and quenching temperatures.

BRASS

YIELD POINT. The Yield Point, W. Koester. Metallurgist (supp. to Engineer), Jan. 27, 1928, pp. 11-13, 1 fig. Investigation of yield phenomena in brass; facts and inferences have bearing upon possible explanation of phenomena of yield in iron and steel; concludes that phenomena of yield are definitely associated with duplex structure of particular kind and suggest that phenomenon of flow under reduced load, once yield has occurred is due to breakdown of support afforded by harder constituent to softer; yield phenomena found in cold-worked metals are due to causes entirely different from those which operate in duplex alloys possessing certain types of microstructure; author ascribes phenomena in work-hardened metal to effects of internal stresses. Abstract translated from Zeit. fuer Metallkunde, Aug. 1927.

BRASS FOUNDRIES

PRACTICE. The Fundamentals of Brass Foundry Practice, R. R. Clarke. Metal Industry (Lond.), vol. 32, no. 6, Feb. 10, 1928, pp. 157-159, 1 fig. Deals with flow of liquid metal; its laws, and question of dry vs. green sand molds; deciding factors in choice of sands; action of crust on gases. (Continuation of serial.)

METALLURGICAL CONTROL. Brass Foundry Tests Every Heat, E. Bremer. Foundry, vol. 56, no. 1, Jan. 1, 1928, pp. 2-6 and 14, 6 figs. Modern brass foundry that maintains most complete metallurgical and chemical department according to present day standards is Mueller Brass Co., Port Huron, Mich.; details of labor-saving devices and methods employed.

PRACTICE. The Fundamentals of Brass Foundry Practice, R. R. Clarke. Metal Industry (Lond.), vol. 31, nos. 6, 7, 8, 9, 10, 13, 14, 15, 16, 17 and 25, Aug. 12, 19, 26, Sept. 2, 9, 30, Oct. 7, 14, 21, 28 and Dec. 23, 1927, pp. 123-125, 147-148, 175-177, 201-202, 289-290, 319-320, 341-342, 366-367, 393-394 and 582-583, 48 figs. Aug. 12: Physical and chemical phases of foundry; preventing warped castings and core-blows. Aug. 19: Calculating metal pressures; pouring pressure desirable. Aug. 26: Correct practice for green-sand molding; buoyancy; action and reaction. Sept. 2: Reaction at surfaces; condition and "body" of sand; grades of sand; radiation and concretion; volume and surfaces. Sept. 9: Expansion, construction, and cohesion; remelting metal; pouring temperature; practical applications; logical sequence of operation; molding castings vertically. Sept. 30: Shrinkage and low cohesion; radiation and concretion; chilling inadequate for overcoming shrinkage; concealed cavities. Oct. 7: Results of shrinkage; effect of gravity. Oct. 14: Difficulties loose pattern work, and fallacies entertained in practice. Oct 21 and 28: Flow of liquid metal; its laws, and question of dry green-sand molds. Dec. 23: Depth of sand to be rammed; principles of gaseous activity; mold gases and their origin.

CASE HARDENING

CARBON DIFFUSION. The Diffusion of Carbon in Carburized Iron. Fuels and Furnaces, vol. 6, no. 2, Feb. 1928, pp. 211-212, 6 figs. Investigation by E. Zingg; microscopic examination showed conclusively that with steel samples within temperature range of 1200 to 1470 deg. Fahr., surface zones had been transformed into cementite layer; results show that true diffusion takes place only up to content of saturated mixed crystals, while with reaction diffusion, content of highest chemical composition may be attained. Translated from Stahl und Eisen.

CASTING

CENTRIFUGAL. Machine Shop Patents. Machy. (Lond.), vol. 31, no. 797, Jan. 19, 1928, p. 511, 2 figs. Patent for centrifugal casting machines; mold tube is carried on vertical shaft driven by bevel gearing; periphery of mold formed by six segments.

CENTRIFUGAL. Spun-Sorbitic Cast Iron. Automobile Engr., vol. 18, no. 238, Feb. 1928, p. 59, 3 figs. New process for producing cylinder barrels by centrifugal casting; experimental work to determine conditions necessary for successful casting; improvement in resistance to wear; subjecting cylinder castings to special cooling treatment whilst in mold during rotation.

COOLING AND TEMPERATURE, EFFECT OF. Notes on Rate of Cooling and Casting Temperature. Foundry Trade Jl., vol. 37, nos. 584 and 589, Oct. 27 and Dec. 1, 1927, pp. 71-72 and 157-158, 3 figs. Relation between temperature fall and elapsed time; internal behavior of rate of cooling; critical points; increased rate of cooling lowers critical points; influence of composition on critical points; undercooling or surfusion. Dec. 1: Rate of cooling in relation to grain size; segregation and shrinkage; influence of casting temperature.

DESIGN. Some Faults in the Design of Castings, W. J. May. Mech. Wld., vol. 82, no. 2137, Dec. 16, 1927, pp. 447-448, 7 figs. Suggestions for castings made with cast-on flanges and other projections; castings in which ribs are introduced for purpose of stiffening and adding extra strength; design-

ing of machines having parts awkward to mold or cast; question of suitability of metal for particular purposes.

CASTINGS

STRENGTH PROPERTIES. The Variability of Castings, G. Schreiber. Metallurgist (supp. to Engineer), Jah. 27, 1928, pp. 10-11, 1 fig. Discusses mechanical properties of castings; work was carried out in laboratory of electrochemical works of I. G. Farbenindustrie at Bitterfeld, and is largely concerned with proprietary magnesium alloy "Elektron," but data utilized extend to steel and cast iron and also to three aluminum alloys; author confines his attention to ultimate tensile strength and percentage elongation. Abstract translated from Zeit. fuer Metallkunde, Nov. 1927.

CAST IRON

DEFECTS. Piping in Its Relation to Eutectic Composition (Das Lunkern in Beziehung zur eutektischen Zusammensetzung), B. Osann. Giesserei, vol. 15, no. 3, pp. 49-51, 5 figs. Author submits new hypothesis according to which piping should not develop in eutectic alloys; it is shown that in pearlitic cast iron, piping tendency is eliminated or greatly diminished.

DEVELOPMENTS. Recent Developments in Cast Iron and Foundry Practice. Brit. Cast Iron Research Assn.—Bul., no. 19, Jan. 1928, pp. 14-18. Reviews paper by Moore and Lyon on fatigue tests on cast iron; paper by Schwarz on tests of cast iron, results being given in tabular form; tests carried out by British Oxygen Company on strength of cast iron at very low temperatures; malleable cast iron specifications.

GRAPHITIZATION. The Graphite Eutectoid in Cast Iron (Das Graphiteutektikum im Gusseisen), E. Schüz. Giesserei, vol. 15, nos. 4 and 5, Jan. 27 and Feb. 3, 1928, pp. 73-78 and 102-108, 27 figs. Review of different theories of solidification processes in different groups of iron with higher carbon content; modern views on removal of graphite from molten iron. Includes number of diagrams and photomicrographs.

HARDNESS. Does Hardness Govern? E. Bremer. Foundry, vol. 56, no. 3, Feb. 1, 1928, pp. 106-108. Points out that correlating of Brinell hardness with other hardness qualities is complicated; it is believed that definite steps should be taken to investigate various relationships and establish Brinell hardness test as indicator of certain qualities on standard basis; need for this is exemplified in number of replies received in answer to letters requesting information on value of Brinell test.

MACHINABILITY AND WEAR. Data on Machinability and Wear of Cast Iron, T. H. Wickenden. Soc. Automotive Engrs.—Jl., vol. 22, no. 2, Feb. 1928, pp. 206-212, 10 figs. Hardness or chemical composition of iron, by itself, no indication of wearing property nor of its machinability; excess carbide spots or phosphides of high phosphorus content in cylinder blocks deleterious; nickel, or nickel and chromium, intelligently added to iron to obtain correct microstructure for good wearing properties and machinability; analyses of cylinder blocks, pistons, clutch plates, brake drums, cams, and forming dies, in which nickel and chromium have been used; improvements secured.

NICKEL AND CHROMIUM IN. The Influence of Nickel and Chromium on Cast Iron, Foundry Trade Jl., vol. 38, no. 599, Feb. 9, 1928, p. 100. Review of recently published work by D. M. Houston, R. S. Poister, E. Piwowarsky, Young, Sipp and Roll, and Turner and Hanson.

NICKEL AND CHROMIUM IN. The Influence of Nickel and Chromium on Cast Iron, A. B. Everest. Brit. Cast Iron Research Assn.—Bul., no. 19, Jan. 1928, pp. 7-9. Supplement to Bulletin No. 16, April 1927, giving details of papers on influence of nickel and chromium on cast iron.

PROPERTIES. Mechancial and Physical Properties of High Grade Gray Cast Iron and Principles Underlying its Production (Hochwertiger Grauguss, seine mechan.-physikal. Eigenschaften und die Grundlagen zu seiner Erzeugung), E. Zimmermann. Zeit. fuer die gesamte Giessereipraxis, vol. 49, nos. 1, 2, 3, 4, 5 and 6, Jan. 1, 8, 15, 22, 29 and Feb. 5, 1928, pp. 2-4, 17-18, 28-29, 38-39, 48-49 and 54-56. Forms in which carbon occurs in cast iron; flake graphite, carbon and its influence on melting temperature; changes in structure after solidification; iron-graphite system; sub-cooling; graphitization.

PROPERTIES AT LOW TEMPERATURE. The Properties of Cast Iron at Low Temperatures, with Special Regard to Cast Iron Pipe (Die Eigenschaften von Gusseisen bei niedrigen Temperaturen unter besonderer Berucksichtigung von Gussrohren und Gussrohrleitungen), C. Pardun and E. Vierhaus. Giesserei, vol. 15, no. 5, Feb. 3, 1928, pp. 99-102, 5 figs. Investigations of castings at temperatures below freezing point, showing that, in contrast to steel, mechanical properties of cast iron are not seriously affected by ordinary winter temperatures; noticeable changes occur only at very low temperatures—80 deg. Cent.).

STEEL-MIX. The Manufacture of Steel-Mix Gray Cast Irons, with Special Reference to their Treatment in the Foundry, A. Smith. Foundry Trade Jl., vol. 38, no. 598, Feb. 2, 1928, pp. 77-79, 2 figs.

By adoption of suitable mixtures and correct melting technique, it is possible to make with perfect regularity 30 to 60 per cent steel-mix gray cast irons, which will be almost entirely pearlitic in structure, readily machinable and yet possess vastly superior properties to gray irons made from pig irons alone or pig irons mixed with cast iron scrap; classification of semi-steel cast iron; graphite in semi-steel cast iron; cupola design; how to add manganese; rod feeding not advocated.

WEAR. The Wear of Cast Iron. Brit. Cast Iron Research Assn.—Bul., no. 19, Jan. 1928, pp. 9-13. Review of recent experimental work, covering automobile pistons and cylinders; brake blocks; locomotive valve rings and work hardening.

CHAINS

BRITTLENESS. Brittleness in Chains Links as Affected by Proofing and Annealing. I. R. Mulder. Engineering, vol. 125, no

3234, Jan. 6, 1928, pp. 2-4, 8 figs. Results of tests on steel chains carried out at Koninklihke Nederlandsche Grofsmederij, Leyden, Holland, to supplement tests described by C. G. Lutts published in Proceedings of Am. Soc. of Testing Materials, vol. 24, 1924; material used comprised 30 new links, of which 15 were fitted with cast-iron studs; tests were also made on 20 studless links cut from light-ship cable; results from these and other tests show ultimate strength is little affected by annealing but toughness is increased.

CHROMIUM STEEL

ALUMINUM IN. Physical Properties of Several Chromium-Aluminum and Chromium-Nickel-Aluminum Steels, V. O. Homerberg and I. N. Zavarine. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb., 1928, pp. 297-301 and (discussion) 301-304, 3 figs. Affinity of aluminum for nitrogen in ammonia case hardening process has resulted in manufacture of special alloy steels containing aluminum together with chromium or with chromium and nickel; subjection of these steels to action of ammonia gas at comparatively low temperature, results in production of very hard surface without deformation of material and without any subsequent heat treatment; investigation of physical properties of three steels containing aluminum; includes curves and tables showing physical properties of steel.

CHROMIUM-VANADIUM. Correlating Test-Date on Heat-Treated Chromium-Vanadium Steels, E. J. Janitzky. Soc. Automotive Engrs.—Jl., vol. 22, no. 1, Jan. 1928, pp. 55-59 and (discussion) 59-64, 6 figs. Work performed and procedure followed in correlating test results on specimens of heat treated S. A. E. chromium-vanadium steel 6130 as basis for revision of physical-property charts for certain automotive steels; 115 tests including complete chemical analysis, tensile-strength, and Brinell, scleroscope and Rockwell hardness tests; results given in frequency or probability curves.

COBALT

ELECTROLYTIC. Study of the Physical Properties of Electrolytic Cobalt and its Alloys with Iron, W. C. Ellis. Rensselaer Polytechnic Inst.—Eng. & Sci. Series, no. 16, June 1927, 57 pp., 31 figs. Historical resume of properties of iron-cobalt system; preparation and properties of electrolytic cobalt; some physical properties of iron-cobalt system. Bibliography.

COPPER

CORROSION. On the Corrosion of Copper and Brass, K. Inamura. Tohoku Imperial University—Sci. Reports, vol. 16, no. 8, Dec. 1927, pp. 999-1008, 13 figs. Using rolled plate of copper, 70:30 and 60:40 brasses as materials, relation between concentration of various reagents and corrosion loss, and effect of corrosion products upon further progress of corrosion was studied. (In English.)

HARDENING. Laying the Hard Copper Ghost. Foundry, vol. 56, no. 2, Jan. 15, 1928, pp. 71-72. So-called lost art of hardening copper is no secret from present-day metallurgists; methods of hardening; determination of Brinell hardness upon different forms of copper and upon sample of so-called hardened copper; are shown in table.

COPPER ALLOYS

COPPER-SILICON. Copper-Silicon Alloys of High Copper Content (Zur Kenntnis der Kupfer-Siliciumlegierungen mit grossem Kupfergehalt), W. Ceiss and J. A. M. van Liempt. Zeit. fuer anorganische u. allgemeine Chemie, vol. 168, no. 1, Nov. 21, 1927, pp. 31-32. Experimental study of mechancial, electrical and chemical properties of copper-silicon alloys containing not more than 6 per cent silicon, particularly resistance to corrosion.

CORROSION

RESEARCH. New Methods of Corrosion Research (Neue Wege der Korrosionsforschung), J. Czochralski and E. Schmid. Zeit. fuer Metallkunde, vol. 20, no. 1, Jan. 1928, pp. 1-7, 15 figs. Describes application of strength investigation for determination of velocity of dissolution of corrosion of metals in chemical reagents; dissolving speed of technical aluminum wire in caustic soda solution, hydrochloric acid and copper-chloride solution is determined for room temperature; dissolving speed of hard wire was in all cases greater than of annealed wire.

SEA WATER, IN. Corrosion of Metals in Sea Water and Its Prevention (Korrosion und Schutz der Metalle im Seewasser), H. Bauermeister. Schiffbau, vol. 28, no. 21, Nov. 2, 1927, pp. 469-471. Resistance to corrosion of standard metals and most common alloys as determined at German Government testing laboratories.

TESTS. Corrosion Tests. Metallurgist (supp. to Engineer), Jan. 27, 1928, pp. 2-3. Review of address by Bengough to Inst. of Metals dealing with complexity of corrosion phenomena and great number of factors which go to determine rate of corrosion in any given set of conditions; it was pointed out in discussion on lecture, both by Rosenhain and Vernon, that difficulty of testing corrodibility really arises only where finer distinctions have to be measured; it seems that testing of specific properties which affect durability and corrosion resistance, may yet be pursued with immediate advantage.

CRYSTALS

ANNEALING, EFFECT OF. Effect of Annealing on Cold-worked Single Crystals of Silicon-ferrite, H. O'Neill. Am Inst. Min. and Met. Engrs.—Tech. Pub., no. 48, Feb. 1928, 19 pp., 13 figs. Subcutaneous deformation markings are revealed on etching polished sections of slowly cold-worked single crystals of silicon-ferrite; annealing these cold-rolled single crystals at 250 deg. Cent. either shortly after rolling or after rest of 20 months gave no measurable rise of scratch hardness; effect of long time interval between deformation and heat treatment is to retard both softening and recrystallization.

CUTTING TOOLS

WELDING TIPS. Cutting Tools with Welded Tips of High Speed Steel (Schneidstaehle mit aufgeschweissten Plaettchen aus Schneidmetall), C. W. Drescher. Maschinenbau, vol. 7, no. 2, Jan. 19, 1928, pp. 49-55, 30 figs. Traces development of practice of welded tips in Germany; shaping of welded

tip, methods of welding it on and results of performance tests; development of tungsten-carbide and cobalt-chromium-tungsten alloys; standardization and uses of cutting steels; practical experience with special cutting steels.

WELDED TIPS. Economic Production and Maintenance of Welded-on Cutting Tips (Untersuchung ueber die wirtschaftliche Herstellung und Instandhaltung aufgeschweisster Schneidmetalle), Kreide. Maschinenbau, vol. 7, no. 2, Jan. 19, 1928, pp. 55-56, 2 figs. Economy of welded-on steel tips, cost of production; curves giving diameters of cutting tools of homogeneous materials equal in cost to cutting tools with welded tips.

DIES

BRASS-FORGING. Characteristics of Brass-Forging Dies, F. W. Curtis. Am. Mach., vol. 68, no. 8, Feb. 23, 1928, pp. 319-322, 10 figs. Construction of brass-forging dies and several representative examples of their use; greater accuracy, additional strength and better machining qualities than casting; made similar to steel forging but with many precautions; practice at Mueller Brass Co.; dies of power press type; dies of drop hammer type.

STEEL FOR. Some Suggestions for the Choice of Die-Steel, W. Oertel. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb. 1928, pp. 320-321. Required properties of die steel are high tensile strength and hardness up to temperatures from 752 to 932 deg. Fahr., high resistance against softening by tempering, great wear resistance and great toughness, etc.; when working, if high heating of die can not be avoided steel containing 9 to 11 per cent tungsten or 0.30 per cent carbon and 15 per cent chromium would be preferred; this stainless steel possesses high tensile strength up to tempering temperature of 1022 deg. Fahr.; in addition to high elongation and reduction of area; it does not scale up to temperatures of 1472 deg. Fahr. Translated from Maschinenbau, Oct. 7, 1926, p. 878-880. See reference to original article in Eng. Index, 1926, p. 708.

DROP FORGING

ELECTRIC HAMMERS. A Converted Drop Hammer Plant. Engineer, vol. 145, no. 3759, Jan. 27, 1928, pp. 110-111, 5 figs. Drop-forging shop at Chippenham, Wiltshire, works of Westinghouse Brake and Saxby Signal Co. contains three lines of drop hammers; whole plant has been converted to electric driving, and each hammer has been fitted with Brett's latest design of friction-driven lifter.

EQUIPMENT. Drop Forging Industry and Equipment, M. S. Reed. Heat Treating and Forging, vol. 14, no. 1, Jan. 1928, pp. 32-33 and 40. Present status of industry and improvements in methods and equipment to meet changed conditions; four-roll board-drop hammer; speed and accuracy of hammer operation; withdrawal of obsolete equipment; new uses found for drop forgings.

ELECTRIC FURNACES

CONTROL. Automatic Control of Electric Furnaces, L. G. Bean. Elec. Light and Power, vol. 6, no. 2, Feb. 1928, pp. 64-70 and 91, 10 figs. Tells what automatic control accomplishes, how it operates, what instruments are used for it and how they are connected to various kinds of furnaces; advantages of automatic control are generally conceded to be; more even product; lower labor charges; longer life of furnaces due to not overheating; saving of fuel.

CONTROL. Automatic Control of Electric Furnaces, L. G. Bean. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June 1927, pp. 45-51. Demands of automatic control are of two types, first being by far most common; (1) when it is desired to bring furnace to predetermined temperature and hold it there, (2) when it is desired to vary temperature of furnace according to definite established time cycle; there are basically five types of automatic temperature controls on market; liquid or gas-filled thermometer controllers; millivoltmeter or depressor bar pyrometers; potentiometers; resistance thermometers; bimetallic expansion thermometers; most important feature in installation of automatic temperature control, is location of sensitive element or thermocouple of controller.

DEVELOPMENTS. Development of the Electric Furnace, H. E. Bromer. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June, 1927, pp. 18-21. General treatment of subject covering uses for steel and iron casting and foundry work.

FOUNDRIES. Electro-Metallurgy of Steel for Foundry Use, R. J. Richardson. Foundry Trade Jl., vol. 38, no. 597, Jan. 26, 1928, pp. 61-64, 10 figs. Reviews history of development of the electric furnace; describes modern Heroult direct arc, three-phase furnace; furnace linings; basic operation of electric furnaces; removal of elements; acid practice; reducing acid conditions; acid vs. basic electric steel.

HEAT TREATING. Electric Furnaces for Tempering Axes. J. S. Keenan. Elec. News, vol. 37, no. 3, Feb. 1, 1928, pp. 48-49, 2 figs. Canadian garden-tool manufacturer reduces labor costs 50 per cent by installing two automatic-temperature controlled furnaces, one of furnaces is rated at 75 kw. at 220 volts, three-phase, while other is rated 47 kw.; former will heat treat 325 axes per hour each weighing 4 pounds.

HEAT TREATING. Rotary Hearth Furnace Automatically Discharges Parts Into Quench Tank. Fuels and Furnaces, vol. 6, no. 2, Feb. 1928, pp. 197-200, 3 figs. Electrically heated furnace with rotary hearth and automatic dumping mechanism, placed in operation in heat treating department of The Nash Motors Co., Racine, Wis., is used in heat treatment of various types of automobile parts such as steering knuckles, gear blanks, piston pins, etc.

HEAT TREATING. Oven Can Heat 400,000 Pounds of Steel at One Time. Iron Trade Rev., vol. 82, no. 8, Feb. 23, 1928, p. 509, 1 fig. Description of electric heat treating furnaces of A. O. Smith Corp.; 400,000 lb. of metal heated at one time to maximum of 1650 deg. Fahr.; capacity of 3000 kw.; used for heat treatment of steel after fabrication.

HEAT TREATING. Conditions Required for Tempering Furnaces (Les conditions à remplir par les fours à revenir). Pratique

des Industries Mecaniques, vol. 10, no. 11, Feb. 1928, pp. 467-468, 2 figs. Description of principal conditions to fulfill for steel tempering with special attention to "Homo" system of electric furnace, developed in America.

HIGH FREQUENCY. Steel Making in the High Frequency Induction Furnace, F. Wevor and G. Hindrichs. Metallurgist (supp. to Engineer), Jan. 27, 1928, pp. 6-7. Metallurgical conditions which prevails when one of these types of induction furnace is used for steel melting; authors deal with number of factors which determine usefulness of this type of furnace for steel-making purposes, confining their consideration, however, mainly to comparison of induction furnace products with those of crucible steel process. Abstract translated from Archiv fuer das Eisenhuttenwesen, no. 3, Nov. 1927, p. 345.

HIGH FREQUENCY. Power Factor in Induction Spark Furnaces of High Frequency (Le facteur de puissance dans les fours a induction a haute fréquence à etincelles), R. Dufour. Jl. de Physique et le Radium, vol. 8, no. 12, Dec. 1927, pp. 508-521, 10 figs. Scheme of operation of spark furnace; intensity at end of charge and discharge; heat liberated; calculation of power factor from characteristics of system.

INDUCTION. Electric Smelting Advancement, G. H. Clamer. Metal Industry (N. Y.), vol. 26, no. 2, Feb. 1928, pp. 68-70, 3 figs. Recent developments in induction furnace and progress it has brought about in melting of metals; Ajax-Wyatt furnace has revolutionized brass melting practice in wrought brass industry; is now also being adopted in foundry industry. (Continuation of serial.)

MELTING. Presents Cost Data on Electric Furnace Melting, J. B. Meier. Foundry, vol. 56, no. 3, Feb. 1, 1928, pp. 93-98, 5 figs. Author presents unbiased and accurate continuous record of actual conditions as encountered in foundry with which he is associated, dealing solely in rough castings; includes graphic representation of electric furnace operation over period of 8 months; résumé of cost per ton.

MELTING. Electric Melting, H. S. Primrose. Foundry Trade Jl., vol. 38, no. 598, Feb. 2, 1928, pp. 81-84. Deals with three types of furnaces which have proved to be very successful in operation; these are Heroult furnaces for ordinary and alloy steels, Ajax-Wyatt furnaces for melting brass, Ajax-Northrup furnaces for melting special alloy steels, high-copper alloys, nickel-copper alloys, pure metals and high melting point metals.

MIGUET. New Miguet Electric Furnace with Continuous Electrodes (Le nouveau four électrique Miguet à electrode continue), R. Sevin. Jl. du Four Electrique, (supp.), vol. 37, no. 1, Jan. 1928, pp. 5-8, 5 figs. Description of electric furnace at Montricher using single-phase current; incoming current at 5000 volts transformed by 5 transformers; operation also described and complete installation.

MIGUET. Electrochemical Reduction Furnaces with Systematic Heterogeneous Feeding (Reduction électrochimique avec alimentation méthodiquement hétérogéne des fours), P. Miguet. Jl. du Four Electrique (supp.), vol. 37, no. 1, Jan. 1928, pp. 3-5, 2 figs. Description of electric furnace which produces steel direct from ore and can also obtain as many complex alloys as refined metals; new method of feeding is patented in France under No. 606,428, which gives all important information.

MIGUET. The Electric Furnace of 100,000 Amperes of the Electrometallurgical Co. of Montricher (Le four electrique de 100,000 amperes de la Societe Electrometallurgique de Montricher), P. Bergeon. Jl. du Four Electrique (Supp.), vol. 37, no. 1, Jan., 1928, pp. 1-3, 2 figs. Description of electric furnace using single-phase current obtained from three-phase by Scott transformers and use of two electrodes; furnace is 2.3 m. diameter and 1.2 m. high.

OPERATION. Operation and Regulation of Electric Furnaces Studied Diagrammatically (Le fonctionnement et le réglage des fours électriques étudiés par le diagramme), P. Bergeon. Revue de Métallurgie, vol. 24, no. 11, Nov. 1928, pp. 683-694, 6 figs. Diagrams and formulas are given illustrating dependence of power factor on electrical conditions and method of operating electric furnace operated from transformer; results obtained suggest new method of regulating arc furnace by suitable manipulation of electrodes which is especially advantageous when voltage of primary is adjustable and furnace has relatively high inductance.

POSSIBILITIES. The Potentialities of the Electric Furnace Examined. Foundry Trade Jl., vol. 38, no. 599, Feb. 9, 1928, p. 101. Discussion of paper by H. S. Primrose; takes up question of relative costs; electric ore smelting furnaces; mechanically charging electric furnaces; comparative costs other than pit-fired crucibles.

PROBLEMS. Electric Furnaces. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June, 1927, pp. 52-84. Contains following abstracts: Melting of Brass in Electric Furnaces, E. L. Crosby; Accomplishments and Comments by Users, Irving; metallic resistance furnace, L. H. Knapp; Electric Melting of Iron and Steel, G. L. Simpson, Industrial Electric Heating Statistics, W. S. Scott; Labor Saving Devices Possible with Electrically Heated Furnaces, A. H. Vaughan; Application of Electrical Heat and Its Relation to Production Costs, R. P. Ellis; Continuous Electric Furnace Carburization, H. E. Martin.

TUBES. "Resist" Tubes for Electric Furnaces (Tuyaux "Résisto" pour fours electriques). Jl. du Four Electrique, vol. 37, no. 1, Jan. 1928, p. 14, 1 fig. Describes flexible water tubes used to carry circulating water to electrode holders in electric furnaces; tubes are spirally constructed and made of copper alloy.

TYPES. Experiences with Electric Furnaces, H. B. Knowlton. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June, 1927, pp. 31-34. Paper covers number of years' experience with several types of furnaces, including furnaces, which are used in heat treatment of steel; furnaces criticized

are obsolete types, requirements of ideal furnace; cost of purchase and installation; carburizing furnaces. Abstract.

TYPES. Stellite and the Development of the Electric Furnace, J. R. Brown. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June, 1927, pp. 21-23. Describes four kinds of electric furnaces; indirect-arc, direct-arc with non-conducting hearth, direct-arc with conducting hearth, and induction furnace; in manufacture of stellite, single-phase Snyder furnace having direct arc with conducting hearth is used.

ELECTRIC HEATING

INDUSTRIAL APPLICATIONS. Résumé of Industrial Electric Heat, J. E. Nelson. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June, 1927, pp. 7-13. Enumeration of various branches of Industry making use of electric heat to their advantage and applications to specific cases; largest single demand for heat in production processes, other than in melting of metals, lies in field of heat treatment of metals; inherent characteristics of electricity make it applicable where uniform heat distribution is needed; it can be controlled to degree impossible with other sources of heat, thereby assuring duplication of results at any time, or continuously; electric melting of metals.

FILES

DISKS, METALS FOR. The Manufacture of Circular Files and Rasps (Die Herstellung von Feil- und Raspenscheiben), H. Reininger. Maschinenbau, vol. 7, no. 3, Feb. 21, 1928, pp. 112-116, 14 figs. Uses of rasp and file disks, rotating with speed of 200 to 1500 r.p.m., in working of copper and light metal alloys; materials of construction, their treatment, cementation and nitride case-hardening, annealing, shaping of filing surface and final hardening; macroscopic and microscopic studies of structure.

FORGE SHOPS

METHODS AND EQUIPMENT. The Blacksmith Shop. Elec. Traction, vol. 24, no. 2, Feb. 1928, pp. 78-79, 8 figs. New Coney Island shops of Brooklyn-Manhattan Transit Corporation equipped with latest metal working apparatus; heating and annealing furnaces; welding equipment.

METHODS AND EQUIPMENT. Modernizing Forging Practice, F. W. Manker. Iron Age, vol. 121, no. 6, Feb. 9, 1928, pp. 401-404, 5 figs. Methods and equipment of forging shop at plant of Willys-Overland, Toledo, Ohio; shop is so designed that work progresses from one operation to another with least amount of "float" trucking and handling; all hammers are served with individual forging furnaces and both are so arranged as to allow greatest volume of output with minimum of labor, fuel, power, etc.; separation of heavy from light work.

FORGING

METHODS. Forging Methods and Heating to Forge, W. M. Hepburn. Heat Treating and Forging, vol. 14, no. 1, Jan. 1928, pp. 41-43, 6 figs. Classification of forging methods; relation of proper heating to good results and certain types of furnaces that have been used to advantage; describes continuous-type furnace; end heating for upsetting. Abstract of paper presented before Am. Gas Assn.

PRACTICE. Forging Machine Practice, W. S. Dewell. Machy. (Lond.), vol. 31, no. 797, Jan. 19, 1928, pp. 513-516, 5 figs. Taper upsets, practically all of which are in header tool discussed; each operation should cover that amount of work which will make following operation success in every way; depth of header tool recess greater than length of unsupported stock; diameter at mouth of header tool is controlled by length of metal to be upset; greatest length of unsupported stock successfully upset is approximately three diameters; examples of connecting rod end and pinion shaft. (Conclusion of article.)

FOUNDRIES

NONFERROUS. New Plant Widens Scope of Output. Iron Age, vol. 121, no. 5, Feb. 2, 1928, p. 328-329, 3 figs. New foundry and machine shop of Hills McCanna Co.; larger sizes of individual castings and heats from wider range of nonferrous metals obtained; 11 oil-fired furnaces; molding machines, Pridmore stripper, 2 electrically operated sand riddles and sand mixer; small molds made in steel flasks; core room, core ovens, gate and riser cutting-off machines and sand-blast equipment; duorail and monorail systems; fuel oil from central pumping station for handling material.

PRACTICE. A Session on Foundry Practice. Foundry Trade Jl., vol. 38, no. 599, Feb. 9, 1928, pp. 99-100. Discussion covering foundry costs, steel castings, chemist's place in industry, and core oils.

REFRACTORIES. The Selection and Use of Refractories for Iron Foundries, C. Presswood. Foundry Trade Jl., vol. 38, no. 596, Jan. 19, 1928, pp. 43-47 and (discussion) 47, 3 figs. Desirable properties which refractory material may be called upon to withstand are: intense heat, chemical action of fluxes, physical and mechanical conditions, changes of temperature, oxidizing and reducing atmospheres and rough handling before use; presents curve showing behavior of refractory material under increasing temperature conditions.

TECHNICAL TERMS. A Lexicon of Technical Terms, O. W. Potter. Foundry, vol. 56, nos. 1, 2 and 4, Jan. 1, 15, and Feb. 15, 1928, supp. plates. Foundry data sheets. (Continuation of serial.)

FURNACES, ANNEALING

CONTINUOUS. Continuous Annealing Furnaces, F. W. Manker. Heat Treating and Forging, vol. 14, no. 1, Jan. 1928, pp. 47-50 and 54, 4 figs. Progress in art of and equipment for annealing steel sheets and patenting wire; Victor peninsular furnace for small parts; elements influencing progress; efforts to eliminate pits and scratches and water-cooled shafts; problem of wasters not solved. Abstract of paper delivered before Engrs. Soc. of West. Penn.

FURNACES, FORGING

COMBUSTION CHAMBERS. Improved Combustion Chamber for Forges, Ry. Jl.,

vol. 34, no. 2, Feb. 1928, p. 23. Improved combustion chamber for shop forges designed by F. J. Butsch, foreman smith of South. Pacific shops at El Paso, Tex.; furnaces after being warmed up for few minutes, burn every particle of fuel and there is no smoke given out whatsoever.

PULVERIZED COAL FIRING. Residue Losses in Pulverized-Coal-Fired Heating Furnaces (Beitrag zur Frage der Hoehe des Abbrandes an mit Kohlenstaub gefeuerten Waermoefen), K. Rummel. Archiv fuer das Eisenhuettenwesen, vol. 1, no. 7, Jan. 1928, pp. 499-504, 10 figs. Results of tests on furnaces heated with pulverized bituminous coal, pulverized lignite, mixes gases, lignite producers gases and coke; losses in all cases were found to be due to large extent to position of ingots with regard to gas current, and are greatly dependent on extent to which ingots are swept by exhaust gases.

FURNACES, HEAT TREATING

ELECTRIC VS. FUEL-FIRED. Electric v. Fuel Furnaces, J. W. Urguhart. Machy. (Lond.), vol. 31, no. 799, Feb. 2, 1928, pp. 595-596. Comparsion of cutting; destroying effect from impingement of high pressure incandescent gas that involves employment of strongest refractories; localization of heat; insulating brick or firebrick of electric furnaces lasts indefinitely; two atmospheres compared; equalization of temperature; discharge flue loss; electric heat and treatment of steel.

FURNACES, METALLURGICAL

AIR HEATERS. Metal Air Heater for Industrial Furnaces, W. Derssen. Iron and Steel Engr., vol. 5, no. 2, Feb. 1928, pp. 81-88, 12 figs. Methods in use for heating air in metallurgical furnaces; constructed so to withstand extreme temperature peaks that may occur; fundamental points in construction and operation of metal air heaters; Calco recuperator; Duraloy recuperator; mantle recuperators; Blaw-Knox regenerative air heater.

HARDNESS

TESTING. Methods of Hardness Testing. Am. Mach., vol. 68, no. 5, Feb. 2, 1928, p. 231, 2 figs. Comparison of Brinell and Rockwell readings with table and charts; for ready shop and laboratory reference; Rockwell B reading taken using 1/16-in. diameter steel ball and 500-kg. major load; C. readings taken with conical diamond penetrator and 150-kg. major load.

TESTING. Equipment for Making Physical Tests, J. D. Gat. Heat Treating and Forging, vol. 14, no. 1, Jan. 1928, pp. 38-40. Review of hardness testing methods; discussion of metallography-preparation of specimens and microscope equipment; Mechanical testing laboratory starts with hardness-testing apparatus, Rockwell type or Brinell type to which afterwards can be added small vertical tensile machine and impact tester. (Concluded from Dec. 1927.)

TESTING. A Résumé of the Magnetic Methods Employed in Studying the Mechanical Properties of Matter, S. R. Williams. Instruments, vol. 1, no. 1, Jan. 1928, pp. 29-38, 9 figs. Recent laboratory device for testing hardness of steel balls by magnetic means seems to have some possibilities; experiments described have been selected with idea that apparatus employed in each research is capable of further development by instrument makers into more practical devices.

HEAT TREATMENT

PROCESSES. High Temperature Processes, J. C. Woodson. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June, 1927, pp. 23-31. Brief summary of standard heat treating processes that lie within temperature range of 1000 to 2000 deg. Fahr. and word regarding perfected apparatus available; annealing; heat treatment of metals; carburizing; normalizing; case hardening; malleableizing; vitreous enameling of steel; vitreous enameling of cast iron; patenting of wire.

IRON

ARMCO INGOT. Armco Ingot Iron, R. L. Kenyon. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb., 1928, pp. 240-269, 26 figs. Armco ingot is trade name for commercially pure iron produced in basic open-hearth furnace; in addition to references to published results of various investigators, author presents numerous data from unpublished work of research department of Am. Rolling Mill Co.; describes material, its chemical analysis, microstructure after various treatments and effect of mechanical work and heat treatment on its various physical properties; data is given for iron in form of hot-rolled and cold-rolled bars and shapes, plates, sheets, and wire; tests include tension, compression, shearing, impact, hardness and fatigue tests of various kinds, includes photomicrographs, curves and tables. (To be continued.)

PHOSPHIDE EUTECTIC. A Note on Phosphide Eutectic, A. Allison. Metallurgist (supp. to Engineer), Jan. 27, 1928, pp. 3-4, 4 figs. In connection with chilled iron rolls, certain phenomena have been observed in three cases, which are of interest in regard to solidification of phosphide eutectic; includes photomicrographs.

PRODUCTION FROM FERROUS SANDS. Making Sponge Iron from Ferrous Sand in Japan. Foundry Trade Jl., vol. 38, no. 597, Jan. 26, 1928, p. 64. Attempt is being made in Japan to utilize large deposits of ferrous beach sand on eastern coast of Japan; process, which has recently been put into operation at Kuji Iron Works, consists in reduction of common oxides of iron—hematite, limonite, magnetite and residues from roasting of iron pyrites—at temperature low enough to prevent melting of any of iron or other constituents of iron ore; this temperature lies between 500 and 1000 deg. Cent.; no flux is used.

IRON ALLOYS

IRON-NICKEL. On the Determination of the Heterogeneous Field in the Iron-Nickel System, K. Honda and S. Miura. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb., 1928, pp. 270-279 and (discussion) 279-281, 6 figs. By means of dilatometric analysis, heterogeneous field in iron-nickel alloys was determined; addition of nickel to iron was calculated and found to agree with observed

data; variation of coefficient of expansion with concentration in iron-nickel system is discussed in light of structural change of system, includes curves and diagrams.

IRON AND STEEL

BIBLIOGRAPHY. Review of Iron and Steel Literature for 1927, E. H. McClelland. Heat Treating and Forging, vol. 14, no. 1, Jan. 1928, pp. 55-59. Classified list of more important books, serials and trade publications during the year, with few of earlier date not previously announced.

CANADA. Iron and Steel in Canada in 1927. Iron and Steel of Can., vol. 11, no. 2, Feb. 1928, pp. 52-53. Review of Dominion Bureau of Statistics; pig iron production lessened with increased output of steel; increase of importation of pig iron; 6 blast furnaces, operating at year end; ferroalloys; production; steel ingots and castings; prices; United States and World output.

GAS CONTENT. International Co-operation in Determining Gases in Metals. Foundry Trade Jl., vol. 38, no. 599, Feb. 9, 1928, p. 82. U. S. Bureau of Standards distributed sample of ingot iron for gas analyses to University of Sheffield and to Institut fuer Eisenhuettenkunde, Aachen, Germany; results obtained by co-operating laboratories are given.

PRICES. Prices of Steel and Other Products, S. G. Koon. Iron Age, vol. 121, no. 5, Feb. 2, 1928, pp. 330-332, 3 figs. Comparison of prices with those of 1913; Bureau of Labor Statistics discussed; metals lower than most other commodities; changes in past year; probable future course of prices; fairly steady drop in prices of pig iron and finished steel; moderate drop in prices of commodities in general; steel prices well liquidated; influences affecting future prices.

IRON CASTINGS

HARVESTING MACHINERY. Use of Gray and Black-Heart Castings in Construction of Harvesting Machinery (Ueber Grauguss und Schwarzguss fuer Erntemaschinen), H. Jungbluth. Kruppsche Monatshefte, vol. 8, Dec. 1927, pp. 193-203, 20 figs. Chemical composition, microstructure and microstructure of gray and malleable cast iron; parts taking considerable tensile stress should be cast of black-heart iron.

SHRINKAGE HOLES. Shrinkage Holes in Small Gray Iron Castings, P. A. Russell. Foundry Trade Jl., vol. 38, no. 597, Jan. 26, 1928, pp. 55-59, 19 figs. Points out that there is no general agreement as to root cause of shrinkage or drawing, as author prefers to call it; definition of phosphorus; conditions during solidification; effect of composition; drawing of semi-steel cast iron; practical examples; cause of drawing is that expansion due to formation of graphite is practically all absorbed in expanding outer shell of casting, and remaining liquid shrinks.

MANGANESE STEEL

FERRITE REMOVAL. Influence of Manganese and Cooling Velocity on Ferrite Removal from Manganese Steel (Der Einfluss des Mangans und der Abkuelungsgeschwindigkeit auf die Ferritausscheidung), P. Schafmeister and R. Zoja. Archiv fuer das Eisenhuettenwesen, vol. 1, no. 7, Jan. 1928, pp. 505-510, 11 figs. Determination of influence of manganese content and cooling velocity on relation of free ferrite to pearlite; results of Brinell hardness test on castings; position of eutectoid point in relation to manganese content; includes diagram, tables and photomicrographs.

MATERIALS

TESTING. Testing of Materials, F. L. Atkin. Gas World, vol. 88, no. 2270, Feb. 4, 1928, pp. 103-104. Knowledge of exact strength of materials of structure, plant, or pipe system, gives that security and confidence which is necessity to every gas engineer; specifications; tensile test; hardness tests; bending and forging tests. Paper read before Midland Junior Gas Assn.

METAL DRAWING

THIN PLATE. Properties and Tests of Thin Plates for Drawing Processes (Pruefung und Eigenschaften von Feinblechen fuer Ziehzwecke), W. Aumann. Maschinenbau, vol. 7, no. 3, Feb. 2, 1928, pp. 105-110, 18 figs. Apparatus and methods for testing thin plates used in drawing of hollow cylindrical parts Erichsen apparatus and cupping test for determining texture of plate; bending and hardness tests; discusses fluting of rims; criticizes A. E. G. stamping test.

METALLURGY

DEVELOPMENTS. Developments in Metallurgy During 1927, J. Silverstein. Heat Treating and Forging, vol. 14, no. 1, Jan. 1928, pp. 44-46. Among topics considered are: ferrous metallurgy, centrifugal casting, silicon alloys, welding, application of X-rays, chromium plating and nonferrous metallurgy.

DEVELOPMENTS. The Past Year in the Metallurgical Field, S. Goodale. Heat Treating and Forging, vol. 14, no. 1, Jan. 1928, pp. 60-62. Important new advances made during year in making of iron and steel, sponge iron, use of electric heat, rust preventatives, metallography and testing; blast furnace process.

PATENTS. New Patents. Metal Industry (Lond.), vol. 32, no. 6, Feb. 10, 1928, p. 166. Abstracts of new patents on treating zirconium ores; raising yield point of steel alloys by mechanical treatment; malleable alloys of nickel, copper, and iron, aluminum alloys and hardening, etc., screw-cutting taps.

METALS

AIRCRAFT. Aviation Materials at the Materials Exposition of Berlin, 1927 (Werkstoff der Flugtechnik auf der Werkstofftagung 1927), J. Hausen. Zeit. fuer Flugtechnik u. Motorluftschiffahrt, vol. 19, no. 1, Jan. 14, 1928, pp. 9-12, 3 figs. Describes exhibits of materials and structural parts used in construction of aircraft and aircraft machinery; exhibits illustrating corrosion tests and testing of mechanical properties of light metals and alloys.

CABLES AND CHAINS, FOR. Cables and Chains at the Materials Show of Berlin 1927 (Seil und Kette auf der Werkstoffschau 1927), F. Riedig. Foerdertechnik u. Frachtverkehr,

vol. 21, no. 1, Jan. 6, 1928, pp. 23-27, 1 fig. Functions of chains and cables and their bearing on specifications, selection of materials of manufacture and on their design and testing; discussion of properties of welding steel, cast steel, copper and aluminum alloys and other metals used in manufacture of cables and chains; apparatus and methods for testing of cables and chains.

CORROSION. The Effect of Impurities on the Corrosion of Metals, Colin J. Smithells, World Power, vol. 9, no. 50, Feb. 1928, pp. 85-93, 12 figs. Amongst factors which influence corrosion, composition of material is one most important; effect of impurities in metals is discussed in relation to modern electrochemical theory of corrosion; simplest form of corrosion is direct combination between metal and oxygen; number of examples are given of influence of impurities on corrosion of common metals and alloys in service selected to illustrate the various conditions outlined.

CORROSION. Corrosion of Metals as Affected by Time and by Cyclic Stress, D. J. McAdam, Jr. Am. Concrete Inst.—Advance Paper for Mtg., Feb. 28-Mar. 1, 1928, 38 pp., 12 figs. Outline of continued investigation; effect of cyclic stress on corrosion of chromium-vanadium steel and corrosion-resistant steel; stainless steel; effect of cyclic stress on corrosion of alloys of copper and of nickel and of aluminum alloys.

CRYSTALLOGRAPHY. Twinning in Beryllium, Magnesium, Zinc and Cadmium, C. H. Mathewson and A. J. Phillips. Am. Inst. Min. and Met. Engrs.—Tech. Publ., no. 53, Feb. 1928, 8 pp., 7 figs. Beryllium, magnesium, zinc and cadmium, together with mercury, constitute coherent subgroup of periodic system and these metals, excepting mercury, have been studied in sufficient detail by new X-ray diffraction methods to prove their common adherence to hexagonal close-packed type of crystal structure with progressive increase in axial ratio from beryllium to cadmium.

ELASTIC LIMITS. Elastic Limit (Die Elastizizaetsgrenze), O. Foeppl. Zeit. fuer Flugtechnik u. Motorluftschiffahrt, vol. 19, no. 1, Jan. 14, 1928, pp. 2-4, 3 figs. Criticizes conclusions of G. Welter's paper on elastic limits of metals; contends that results of repeated stress testing were overlooked by Welter; claims that in reality elastic limits are far below values given by Welter.

FABRICATED, STANDARDS. Standards for Fabricated Metals. Metal Industry (N. Y.), vol. 26, no. 2, Feb. 1928, pp. 71-73, 2 figs. U. S. Government proposed master specifications for copper-nickel alloys rods, bars, shapes, plates, sheets, and strips; also for brass wire.

FATIGUE. Repeated—Stress Endurance of Metals. Soc. Automotive Engrs.—Jl., vol. 22, no. 2, Feb. 1928, pp. 289-291. Modern viewpoint of fatigue pictures metal yielding first at some point of localized weakness; study of fatigue phenomena in metals is study of elastic straining and of spreading cracks, rather than of plastic straining; design of specimens for fatigue tests; effect of speed of testing on endurance limit; effectiveness of heat treating decreases markedly with increase in cross-section of piece; relation of physical properties; threads; shoulders and fillets; welded joints; locating cracks. From Manual, by H. F. Moore, issued by Eng. Foundation.

GASES IN. Application of a High-vacuum Induction Furnace to the Study of Gases in Metals, P. H. Brace and N. A. Ziegler. Am. Inst. Min. and Met. Engrs.—Tech. Publ., no. 59, Feb. 1928, 21 pp., 7 figs. High frequency vacuum furnace has been constructed capable of melting 13 lb. (6 kg.) of iron and maintaining it at temperatures above 1600 deg. Cent. under pressure less than 0.0005 mm. of mercury; analysis system has been constructed for analyzing quantitatively gases from furnace with respect to hydrogen, nitrogen, oxygen, carbon monoxide, carbon dioxide and water; experimental data showing results obtained from analysis of gases from iron are presented and certain consistencies are pointed out.

INTERATOMIC FORCES. Interatomic Forces in Metals and Alloys, R. G. Mehl. Am. Inst. Min. and Met. Engrs.—Tech. Publ., no. 57, Feb. 1928, 16 pp., 2 figs. It is shown that data on compressibility and internal pressure furnish basis for analysis of hardness of pure metals; it is suggested that electron distribution around atom periphery probably introduces slip-resistance factor in addition to that of crystalline symmetry and interatomic forces.

INTERNAL STRESSES. Internal Stresses. Metallurgist (supp. to Engineer), Jan. 27, 1928, pp. 7-8. Review of recent works by E. Maurer, G. Sachs and Goeler, published in German periodicals; most frequent type of failure is season cracking of drawn rods and tubes made of brass or other alloys of copper, either soon after manufacture or only after some years of service; steel and aluminum members are prone to similar failures, although to much less marked extent; for removal of internal stresses, low-temperature annealing is found to be most effective method; risk of season cracking can be also materially reduced in case of rods, tubes and similar articles by certain mechanical treatment.

PICKLING. Practical Features of Pickling, W. G. Imhoff. Iron Trade Rev., vol. 82, no. 5, Feb. 2, 1928, pp. 318-320, 2 figs. Equipment, production, principles and difficulties and remedies are discussed. (Continuation of serial.)

RESEARCH. The American Society for Testing Materials—Work During 1927. Iron and Steel of Can., vol. 11, no. 2, Feb. 1928, pp. 59-61. Brief review of research work of Society; research to bring out new knowledge on properties of metals; effect of temperature on properties of metals; effects of combined corrosion and fatigue; magnetic analysis and testing; project on numbering of steels discontinued.

ROLLING AND FORGING. Deformation in the Rolling and Forging Processes, G. Sachs. Iron and Steel World, vol. 2, no. 1, Jan. 1928, pp. 35-40, 8 figs. Tests approaching practical conditions show that tearing appearances in rolling of plates and shapes are caused by non-uniform material displacements. Translated from Zeit. fuer Metallkunde.

STRAIN HARDENING. The Cause of Translation Striae and Translation Strain-hardening in Crystals, M. J. Buerger. Am. Inst. Min. and Met. Engrs.—Tech. Publ., no. 54, Feb. 1928, 14 pp. 8 figs.

Most puzzling features observed during single crystal deformation test are appearance of slip striae on surface of crystal and strengthening of specimen; while first phenomenon is mainly of theoretical interest, latter is fundamental to all strain hardening and cold working processes in which deformation occurs by translation.

WORKING LOAD TESTS. A Short Time Test for Safe Working Loads. Metallurgist (supp. to Engineer), Jan. 27, 1928, pp. 8-10, 3 figs. Question arises whether short-time tests can possibly measure any property connected with creep, or throw light on stability of metals at high temperatures; some American metallurgists definitely hold view that plastic deformation does not occur below proportional limit stress as determined in short-time test; to investigate what relation, if any, subsists between these two values research has been carried by A. E. White, (Am. Soc. Mech. Eng., Dec. 5-8, 1927); tensile tests were made at various temperatures on both solid and tubular specimens; to determine creep stress or safe working load, expansion test was used.

MICROSCOPES

METALLURGICAL. The Use of the Microcope in Industry, R. G. Guthrie. Instruments, vol. 1, no. 1, Jan. 1928, pp. 5-27, 49 figs. Microscope discussed, and most important one from purely industrial point of view, is metallurgical microscope or micrometallograph; this type is used almost exclusively for examination of opaque or solid objects; microscope is particularly valuable where heat treated steels are considered; typical microscopic analyses of steels are used in paper.

NICKEL ALLOYS

COPPER-NICKEL. Cupro-Nickel Tubes. Metal Industry (Lond.), vol. 32, no. 5, Feb. 3, 1928, pp. 131-133, 5 figs. Cupro-nickel is alloy highly resistant to corrosion and consequently growing in favor where corrosive influences are likely to be encountered; describes visit recently paid to Kingston Works of Allen Everitt and Sons, Smethwick, specializing in manufacure of cupro-nickel condenser tubes; principal departments of works are melting shops, billet, bar, sheet and strip mills, and tube mills; products are cupro-nickel, copper, brass and bronze.

NICKEL STEEL

INVAR AND ELINVAR. Steels with High Nickel Content, Guillaume. Foundry Trade Jl., vol. 38, no. 596, Jan. 19, 1928, p. 40. Review of lecture given at Conservatoire des Arts et Métiers in Paris; most important of alloys studied was invar; in same series there is another alloy, platinite, which can be welded to glass and does away with use of costly platinum in incandescent lamps; elinvar, produced by author, is alloy with invariable elasticity, use for making spiral springs.

NONFERROUS ALLOYS

ENGLAND. Birmingham and its Nonferrous Metal Industries, F. Johnson. Metal Industry (Lond.), vol. 32, no. 3, Jan. 20, 1928, pp. 93-94. Enumerates application of these metals in Birmingham district to railroads, automobile industry, aircraft, mechanical and electrical engineering, shipbuilding, arms and ammunition, bedsteads, etc.

METALLURGY. Nonferrous Metallurgy in the United States in 1927, W. M. Corse. Metal Industry (Lond.), vol. 32, no. 5, Feb. 3, 1928, pp. 129-130. Review of aluminum developments; copper, aluminum bronze, zinc, magnesium, chromium and lead.

RESEARCH. Research in the Nonferrous Metals Industry, O. F. Hudson. Metal Industry (Lond.), vol. 32, no. 3, Jan. 20, 1928, pp. 81-83. Review of research work during past year; investigations as to cause and prevention of corrosion have made considerable headway, and interesting results have been published as to effects of impurities on copper; research work in light alloys has made considerable advance, and in many directions, considerable advances have been made to our knowledge of metallurgy of nonferrous metals.

SEGREGATION. Segregation in Nonferrous Alloys, R. Law. Chem. Eng. and Min. Rev., vol. 20, no. 232, Jan. 1928, pp. 135-139, 6 figs. Greater part of effect due to migration of portion in bulk during period between initial and final stages of solidification; primary reason for such migration is to be sought in contraction of volume experienced by metal in its passage from liquid to solid state.

WASTE RECOVERY. The Recovery and Utilization of Nonferrous Metallurgical and Foundry Wastes, J. B. C. Kershaw. Metal Industry (Lond.), vol. 32, no. 3, Jan. 20, 1928, pp. 87-88. Deals with suggestions on profitable disposal of scrap from various metals and alloys including aluminum and brass foundry alloys; castings and similar scrap from old automobiles, melting and classifying brass scrap. (To be continued.)

OXIDES

METALLIC. Oxides, Hydrates, Oxyacids, and Salts, Metallic (other than Alkali Manufacture and Cyanogen Compounds). Abridgments of Specifications, class 1 (iii), period 1921-25, 1927, 146 pp. Abridgments of patents for specifications, intended to serve as guides to specifications.

REFRACTORIES

DEVELOPMENTS. The History of the Refractories Industry, J. D. Ramsay. Heat Treating and Forging, vol. 14, no. 1, Jan. 1928, pp. 62-64. Manufacturing process dependent on refractories; growth of industry traced; co-operation between producer and consumer. Paper presented before joint session of Am. Inst. of Chem. Engrs. and Am. Refractories Inst.

TESTS. Determination of Resistance of Refractories to Temperature Changes (Beitrag zur Bestimmung der Temperaturwechselempfindlichkeit feuerfester Baustoffe), W. Miehr, J. Kratzert and H. Immke. Tonindustrie-Zeitung, vol. 52, nos. 4 and 5, Jan. 11 and 14, 1928, pp. 56-60 and 77-78, 13 figs. Report from Didier laboratory and research institute; critical discussion of American water quenching spalling test, pointing out its misleading character and disagreement with practical experience; German modifications of American spalling test; new German test with quenching done by compressed air and water spray; modification of tests for refractories of high silicon content.

SILICON STEEL

MANUFACTURE. Problems in Fabricating

Silicon Steel for Delaware Bridge, H. T. Morris. Eng. News-Rec., vol. 100, no. 6, Feb. 9, 1928, p. 231. Manufacture of steel was conducted in three different open-hearth plants whose melts varied from 75 to 95 tons; economic problems; unless purchaser of silicon steel can correspondingly diminish weight needed for his structure, he will not gain money advantage.

SPRINGS

MECHANICAL, BIBLIOGRAPHY. Bibliography on Mechanical Springs. A. S. M. E. Research Publ., 1927, 68 pp. Indexed according to authors and chronologically; includes subject index to bibliography; for purpose of this bibliography mechanical springs are defined according to their geometrical characteristics; mechanical spring is elastic body whose load-deflection rate and maximum safe-deflection render it suitable for use in mechanical design.

STEEL

AMMONIA SYNTHESIS. Deterioration of Steels in the Synthesis of Ammonia, J. S. Vanick, W. W. de Sveshnikoff, and J. G. Thompson. U. S. Bur. Standards—Technologic Paper, no. 361, Nov. 5, 1927, pp. 199-233, 17 figs. 10 commercial steels, subjected to working conditions of 500 deg. Cent., 100-atmosphere pressure, and 8.3 per cent ammonia yielded results which indicated that: carbon content should be low; increasing chromium was helpful; tungsten was useful; second test made upon series of chrome-vanadium steels showed that: low carbon content was desirable; vanadium contributed no perceptible improvement; chromium in amount of 2.25 per cent stopped selective penetration and intergranular fissuring and limited depth of penetration.

BENDING TEST. The Bending of Steel Overstrained by Tension, J. Muir and D. Binnie. Roy. Tech. College—Jl., no. 4, Dec. 1927, pp. 24-32, 3 figs. Effect which tensile overstrain has on resistance which mild steel offers to compression is investigated by bending tests; conclusion of mattter seems to be that mild steel overstrained by tension does not give well-defined yield-point in compression.

BOILER TUBES. Failures of Boiler Tubes Traceable to Segregated Metal. Power, vol. 67, no. 6, Feb. 7, 1928, p. 250. Gives chemical composition of material machined from inner and outer zones of steel tubes of badly segregated metals; experiments were made in order to determine extent to which pitting and general corrosion in tubes could be ascribed to segregated ingot material.

CORROSION TESTS. Tests by Corrosion of Steels (L' essai de corrosion des aciers). Génie Civil, vol. 92, no. 2372, Jan. 28, 1928, pp. 90-92, 11 figs. Corrosion tests useful for observing manner in which forging or welding has been executed; microphotography of parts broken in service reveals flaws; shows how microphotography is used in connection with corrosion tests to bring out pressure of impurities in metal

GLASS-LINED. Glass Lining Is Open Sesame to Steel for Many Uses, R. T. Mason. Iron Trade Rev., vol. 82, no. 8, Feb. 9, 1928, pp. 388-390, 3 figs. Insulation of enamel lining against corrosive substances enables steel to obtain wider application in fields formerly served by other materials; methods of production of Pfaudler Co.; expansion in application of glass-lined steel to various industries accomplished largely through research work; every shipment of raw material analyzed quantitatively and qualitatively.

HARDENING MECHANISM. The Mechanism of the Hardening of Steel, K. Honda. Fuels and Furnaces, vol. 6, no. 2, Feb. 1928, p. 191. Based upon extensive experimental investigation, author considers volume change during transformation of austenite into alpha martensite as most important factor in formation of dangerous cracks; thermic tension, on other hand, is of lesser importance; also considerable tension still exists in hardened steel. Translated from paper read at meeting of Raw Material Committee of Soc. of German Iron Founders.

HIGH TEMPERATURE, EFFECT OF. Steam at High Temperatures, M. Staeger and P. Bohnenblust. Metallurgist (supp. to Engineer), Jan. 27, 1928, p. 15. Article relates mainly to feedwater, but main question attacked is that of oxidation of steel by hot water and steam, and two possible directions in which attack on steel may occur are discussed; first relates to presence of dissolved free oxygen in boiler water; second is that due to direct reaction between hot steam or water and iron, resulting in formation of iron oxide and free hydrogen. Abtract translated from B. B. C. Mitteilungen, Nov. 1927.

PERMANENT MAGNET. Some Principles Governing the Choice and Utilization of Permanent-Magnet Steels, R. L. Sanford. U. S. Bur. of Standards—Scientific Paper, vol. 22, no. 567, Dec. 9, 1927, pp. 557-567, 7 figs. Addition of substantial percentages of cobalt to composition of permanent magnet steels leads to markedly superior qualities; cost of cobalt steels may be several times that of older types, however, and their use is warranted only under certain circumstances; criteria for comparison of quality of magnet steels are discussed, and conditions under which use of more expensive steel is justified are outlined.

SEGREGATION. Negative or Inverse Segregation and "White Spot" (Ségregation négative, ou inverse, et tache blanche), L. Pichard. Génie Civil, vol. 92, no. 6, Feb. 11, 1928, pp. 132-134, 5 figs. Study of theory of segregation and hardening of steel poured in ingot molds and effects of top and of bottom filling.

STRESS DISTRIBUTION. The Most Important Characteristics and the Theory of Stress as Revealed by Etching Figures (Die wichtigsten Eigenschaften und die Theorie der Fliessfiguren), I. Takaba and K. Okuda. Archiv fuer das Eisenhuettenwesen, vol. 1, no. 7, Jan., 1928, pp. 511-515, 14 figs. Discusses development of etching figures in relation to stress distribution determined optically; relation of figures to elastic limit; theoretical discussion based on crystalline structure.

STRUCTURE. Motion Pictures Visualize Structure and Stress of Steel, H. A. Knight. Iron Trade Rev., vol. 82, no. 5, Feb. 2, 1928, pp. 324-325, 1 fig. New Method of studying iron, steel and nonferrous metals, is receiving attention of scientists; moving-picture camera is principal instrument used, aided at times by microscope, X-ray, fluoroscope, telephoto lens, various screens which

will pass only certain rays of spectrum, and specially sensitized emulsions for recording rays not visible to naked eye.

TEMPERATURE, EFFECT OF. The Properties of Steel at High and Low Temperatures, A. Pomp. Metallurgist (Supp. to Engineer), Jan. 27, 1928, pp. 13-14, 2 figs. Describes work carried out at Kaiser Wilhelm Institut fuer Eisenforschung; empirical limit was assigned to stress for long life, namely, that stress below which extension does not exceed 0.001 per cent in from three to six hours after application of load; effect of temperature on properties of steel is bound up with method of loading; shows curves of impact strength against temperature for mild steel when subjected to different treatments prior to testing; information of direct practical importance is provided by these curves; results of impact strength determinations at various temperatures on chrome-nickel steel and 4-per cent silicon steel. Abstract translated from V. D. I. Zeit., Oct. 27, 1927.

YIELD POINT. The Yield Point in Steel at Various Temperatures, J. Muir. Foundry Trade Jl., vol. 38, no. 588, Feb. 9, 1928, pp. 91-92, 2 figs. Describes simple tension experiments made on good quality of steel wire, kept at various temperatures by passing electric current through wire; great increase in rate of extension at yield point, or great increase in mobility produced by even such moderate temperatures as 50 deg. and 100 deg. Cent., is no doubt connected with great increase, produced by same temperatures, in rate at which elasticity is restored after overstrain.

YIELD POINT. The Yield Point in Steel at Various Temperatures, J. Muir. Iron and Coal Trades Rev., vol. 116, no. 3126, Jan. 27, 1928, pp. 110-111, 2 figs. Tension experiments described were made on good quality of steel wire, kept at various temperatures by passing electric current through wire.

STEEL CASTINGS

SHRINKAGE. Shrinkage and Contraction of Steel Castings, C. W. Serman. Can. Ry. and Mar. World, no. 360, Feb., 1928, pp. 81. Design must lend itself to perfection in formation while casting is changing from liquid to solid state without developing visible and invisible formation defects, or excessive contracting strains as casting cools to normal; design of any casting that approaches uniform section of metal will lend itself to greatest amount of perfection in formation of casting, and will eliminate trouble in service over a long period of time.

SHRINKAGE. Shrinkage of Steel Castings (Beitrag zur Schwindung von Stahlguss), F. Koerber and C. Schitzkowski. Stahl u. Eisen, vol. 48, no. 5, Feb. 2, 1928, pp. 129-135, 9 figs. Describes practical significance of shrinkage deformation and fractures due to variations in shrinkage; results of shrinkage tests on steel castings obtained from open-hearth furnaces with acid and basic processes; influence of chemical composition on shrinkage. (To be continued.)

VALVES AND FITTINGS. Standardizes Riser Design for Steel Valve and Fittings Castings. Iron Trade Rev., vol. 82, no. 7, Feb. 16, 1928, p. 442. New standards in production of cast-steel valves and fittings; dimensions for steel flange fittings, physical properties and design of risers included; 1350-lb. fittings; Walworth Co.'s research work; tests of physical properties of cast steel at from 70 to 1200 deg. Fahr.; proper heat treatment for high-pressure castings; design of fittings for best structural features.

STEEL, HEAT TREATMENT OF

ANNEALING. The Constitution of Steel and Cast Iron, F. T. Sisco. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb., 1928, pp. 305-317, 8 figs. Discusses three steps in annealing operation; (1) heating material to annealing temperature (2) holding steel at proper temperature and (3) cooling from annealing temperature; in each of these steps various structural changes taking place are discussed; operation of annealing as discussed is description of that process as it involves heating to temperature above critical range; includes photomicrographs and iron-carbon diagram, also diagram illustrating annealing of steel.

AUTOMATIC EQUIPMENT. Automatic Heating and Heat Treating Units Synchronize Auto Production, J. B. Nealey. Iron Trade Rev., vol. 82, no. 5, Feb. 2, 1928, pp. 315-317, 3 figs.; also Soc. Automotive Engrs.—Jl., vol. 22, no. 2, Feb., 1928, pp. 166-167, 2 figs. Describes methods and equipment of Fordson Plant of Ford Motor Co., vast majority of heating and heat treating operations are on gas; in steel-making department are 7 basic open-hearth furnaces; main heat treating department, one of largest in world, includes 40 cyanide, 19 continuous and 6 periodic furnaces.

AUTOMOBILE PARTS. Heat Treating Three Thousand Automobile Bumpers Daily, R. A. Fiske. Iron Age, vol. 121, no. 6, Feb. 9, 1928, pp. 391-393, 3 figs. Methods and equipment at plant of Stewart-Warner Speedometer Corp., Chicago; equipment includes two special conveyor-type, gas-fired furnaces, one for hardening and one for drawing; in former, temperatures are automatically controlled within limits of 10 deg. Fahr.; special equipment prevents distortion in quenching; close control of temperature a feature of plant; fuel and air are mixed in central plant.

AUTOMOBILE PLANTS. Modernized Heat Treating Equipment, F. W. Manker. Gas Age—Rec., vol. 61, no. 6, Feb. 11, 1928, pp. 182-184, 4 figs. In designing and equipping its new forge shop and heat treating department, Willys-Overland Co. paid special attention to heating operations; as result it has today one of the most up-to-date modern forging and heat treating plants in the world.

FURNACES AND METHODS. Modern Furnaces and Heat Treating Methods, E. F. Davis. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June, 1927, pp. 34-45. In heating steel for hardening or tempering, four methods are in common practice, viz: heating by immersion in some liquid or molten medium, by direct radiation of heat to work, by conveying heat directly to work by flame or combustion blast, and by transferring heat by air blast previously heated; for hardening, by immersion, lead and cyanide mixtures are most common mediums in use; does not recommend electric heating for cyanide immersion hardening; for heat treating operations between 1400 and 1600

deg. Fahr., electric furnace comes within its widest field of usefulness; electric furnaces nearly all heat by radiation and heating chambers are small, hence heating rate is slow; forge furnaces need much improvement.

HARDENING. Hardening by Reheating after Cold Working. M. A. Grossmann and C. C. Snyder. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb., 1928, pp. 201-215 and (discussion) 215-220 and 281, 19 figs. Authors advance theory which explains phenomenon of hardening of cold-worked steel by reheating at low temperatures; evidences offered point to simple reason for observed changes in strength, hardness and ductility; effects of reheating after quenching and cold working are discussed and their different natures set forth; theory suggested has to do with thin layer of "interblock" material, which increases gradually in thickness as reheating temperature is raised, reaching maximum effective thickness at 600 deg. Fahr.; includes curves and photomicrographs.

METHODS. Heat Treatment of Steel, J. B. Ray. Ry. Jl., vol. 34, no. 2, Feb., 1928, pp. 21-23. Subjects handled include tools, both hand and machine, case hardening, side and main rods and spring steel; annealing; tempering.

METHODS AND EQUIPMENT. Heat Treating Methods and Equipment. Mech. World, vol. 83, no. 2142, Jan. 20, 1928, p. 40, 5 figs. Discussion of essential requirements for successful heat treatment of carbon and high speed tools; proper selection of steels; carbon content must be known so that quenching and tempering temperatures may be judged; forging, hardening and quenching carbon tools and equipment required; cooling system; forging and hardening methods; double-deck furnace. From report submitted at convention of Am. Ry. Tool Foremen's Assn.

QUENCHING. A Practical Study of Rapid Cooling, P. J. Haler. Ry. Mech. Engr., vol. 102, no. 2, Feb., 1928, pp. 99-103, 8 figs. Discussion of methods of quenching, speed plunging and effect produced on various shapes; common methods of quenching; treats of form as determining factor in methods of quenching and how these forms should be treated; relative values of quenching mediums.

QUENCHING. High Temperature Quenching Treatment Applied to Cold Heading Ball Dies of Plain Carbon Tool Steel, F. L. Wright. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb., 1928, pp. 282-293 and (discussion) 293-296, 5 figs. Describes high-temperature quenching treatment for cold forming dies of plain carbon tool steel, and submerged water-spray quenching fixture used for quenching double-end ball-heading dies; increase in quenching temperature from 1470 to 1620 deg. Fahr. followed by suitable tempering treatment has doubled life of dies by increasing their fatigue resistance to or beyond point where dies wear or deform; results of endurance tests made on dies from 6 selected bars of carbon tool steel are compared to small variations in chemical analysis, to normality of tool steel as determined by McQuaid-Ehn carburizing test and to hardness penetration.

SUPERHARDENING. Superhardening of Heat Treated Steel, E. G. Herbert. Iron Age, vol. 121, no. 5, Feb. 2, 1928, pp. 332-333, 2 figs. Possibilities of articles of hard steel being superhardened beforehand as means of resisting wear discussed; subjecting articles to impact of cloud of balls, thus producing work-hardened surface; any soft spot revealed by roughened area; successive tests showed progressive increase in hardness up to certain maximum, and thereafter slow softening; method of superhardening by impact; method of quantity testing for hardness.

TEMPERING. Tempering Changes in Carbon Steels, R. Hay and R. Higgins. Roy. Tech. College—Jl., no. 4, Dec., 1927, pp. 62-76, 7 figs. Tempering changes which take place in quenched steels have been investigated by determining Brinell hardness number, specific volume, yield stress, maximum stress, percentage elongation, and Charpy impact value of specimens which had been water-quenched from 1000 deg. Cent. and tempered from room temperature to 650 deg. at 25 deg. intervals.

STEEL, HIGH SPEED

HARDENING. Defects at the Hardening of High Speed Steel, E. Houdremont and H. Kallen. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb., 1928, p. 323. Difficulties of high speed steel hardening may be traced to fact that hardness of this steel is retained until temperature close to melting is reached; authors discuss particular case of defective hardening. Translated from V. D. I. Zeit., Feb. 19, 1927, p. 269.

MILLING CUTTERS. Evaluating Quality in Heat Treated High Speed Steel by Means of the Milling Cutter, J. B. Mudge and F. E. Cooney. Am. Soc. Steel Treating—Trans., vol. 13, no. 2, Feb., 1928, pp. 221-236 and (discussion) 236-239, 27 figs. Test of heat treated high speed steel in form of milling cutters; it was found that cutters of the same steel hardened by same method check within limits that are sufficiently close for test purposes; no cast cutter has been found to give results comparable to standard high speed steel refined by suitable working; cutters hardened by patented or salt bath processes have not given results comparable to standard high speed steel hardened by open-fire method; includes photomicrographs.

STEEL MANUFACTURE

CHEMICAL REACTIONS. The Application of Theoretical Chemistry to Certain Important Processes of Steel Manufacture (Ueber die Anwendung der theoretischen Chemie auf einige fuer die Stahlerzeugung wichtige Vorgaenge), H. Schenck. Archiv fuer das Eisenhuettenwesen, vol. 1, no. 7, Jan., 1928, pp. 483-493, and (discussion) 495-497, 10 figs. Discusses general laws of thermodynamics as applied to chemical reactions in steel manufacture; application of certain laws of oxidation and reduction of phosphorus and manganese; discussion of deoxidation process.

STELLITE

WELDING WITH. Preventing Excessive Wear in Mill For Crushing and Grinding, B. E. Field. Chem. and Met. Eng., vol. 35, no. 2, Feb., 1928, pp. 96-98, 5 figs. Welding layer of Haynes Stellite to wearing surfaces results in many economies in cement manufacture; Haynes Stellite is cobalt-chromium-tungsten alloy and is supplied in form

of welding rod; it may be readily welded to steel or other metals by either oxyacetylene or electric arc method.

TEMPERATURE MEASUREMENTS

OVENS AND FURNACES. Economical Operation of Ovens and Furnaces. Measurements of Temperature and Heat. L. Jordan. Purdue Univ. Eng. Extension Dept.—Bul., vol. 11, no. 1, June, 1927, pp. 14-18. Mentions methods of solving problems of air heating in ovens which are heated electrically.

TOOL STEEL

HARDENING. The Correct Hardening of Tool Steel, A. R. Page. Flight (Aircraft Engineer), vol. 20, no. 4, Jan. 26, 1928, p. 54L, 1 fig. Home practical experiments to determine correct methods of hardening tool steel; microstructural state of tool just as important as hardness; correct point at which to quench steel is at point where material becomes non-magnetic, and not at point where thermal arrest is complete; Wild Barfield outfit definitely informs operator as to exact point at which to quench his work.

HEAT TREATMENT. Non-Deforming Steels Require Care, W. P. Eddy, Jr. Iron Age, vol. 121, no. 7, Feb. 16, 1928, pp. 468-470, 4 figs. Heat treatment of non-shrinking oil-hardening tool steels to prevent cracking, warping, soft or brittle skin, and to get desired hardness and exact size; procedure to avoid cracking; open fire and muffle liable to produce soft skin; pack hardening requires slightly higher quench; cyanide baths may produce brittle surfaces; claims for salt mixtures exaggerated; recommended heat treatments.

SPECIFICATIONS. Tools and Tool Steel Specifications, E. S. Lawrence. Heat Treating and Forging, vol. 14, no. 1, Jan., 1928, pp. 26-31 and 37, 11 figs. Factors to be considered in specifying for purchase of tool steels; classification, chemical limits, hardening and tempering practice; importance of microscopic examination; presents table giving mechanical limits of carbon tool steels; heat treating features; photomicrographs. Bibliography.

WELDING

STAINLESS STEEL. Welding of Non-Corrosive Steels (Ueber das Schweissen von Rostsicheren Staehlen), W. Hoffmann. Autogene Metallbearbeitung, vol. 20, no. 24, Dec. 15, 1927, pp. 337-345, 18 figs. Report from welding laboratory of Gebr. Boehler steel works of Duesseldorf on welding tests of chromium and chromium-nickel steel plates; metallographic, microscopic studies of welds; oxyacetylene process used without modifications; in arc welding electrodes must be coated; welds of non-corrosive steels are superior to welds of ordinary steels and by reducing carbon, silicon and manganese contents welding increases resistance to corrosion.

WELDS

BRITTLENESS AT RED HEAT. Red-Shortness of Weld Metal, A. H. Goodger. Welding Engr., vol. 13, no. 2, Feb. 1928, pp. 39-43, 6 figs. British Welding engineers investigate causes of brittleness of some welds at red heat, and means of controlling crystalline structure; many fusion welds red-short and particularly with electric arc welds; representative compositions of fluxes in commercial use; other effects of fluxes; passage of metal through arc; effect of carbon content of electrode on red-shortness of weld; tensile strength; bend tests; carbon contents of welds; microstructure; welds made in oxygen gas. Paper read before Inst. Welding Engrs.

TESTING. The Testing of Welds. Eng. Progress, vol. 9, no. 1, Jan. 1928, p. 24. Special Committee on Welding of Verein Deutscher Ingenieure has decided to recommend simple bending test; test code has been worked out which specifies exactly how test is to be carried out, and what properties test piece must show.

WIRE

ALUMINUM. Proposal for the Standardization of Aluminum Wire (Entwurf fuer die Normung von Leitungsaluminium). Zeit. fuer Metallkunde, vol. 20, no. 1, Jan., 1928, pp. 14-15. Results of work and discussions of committee for standardization of aluminum wire carried out jointly by Assn. of German Electrical Engineers and German Metallographic Society.

MANUFACTURE. Rod Rolling and Wire Drawing, J. P. Bedson and J. S. G. Primrose. Iron and Steel World, vol. 2, no. 1, Jan., 1928, pp. 27-30. Discusses various processes involved in steel wire manufacture from billet to finished part; rolling of billets in rods for wire drawing; discussion of wire-drawing process; metallurgical requirements of wire and physical characteristics.

STEEL, COLD ROLLING. The Cold Rolling of Steel Wire, H. Goldschmidt. Wire, vol. 3, no. 2, Feb., 1928, pp. 43-46, 18 figs. Rolling process applied to small gage wire shows advantages; choosing right caliber; rhombus with vertex angle of 100 deg.; principle of automatic lead proved very advantageous in all our experiments; transfer from rhombus-profile to round cross-section of finished wire facilitated by intermediate profile; comparative breaking tests with drawn and rolled wire.

STEEL, DRAWING AND BLUEING. Effect of Drawing and Blueing on the Physical Properties of Wire, J. D. Brunton. Wire, vol. 3, no. 2, Feb., 1928, pp. 47-49 and 66-69, 3 figs. Modifications in physical properties due to wire drawing depend chiefly on structure of steel before tempering and on amount of cold work put on it; tensile strength increased with corresponding reduction in ductility as measured by elongation; fatigue; elasticity can be increased considerably in wire by blueing or heating to temperatures below 400 deg. Cent.

STEEL, TESTING. The Yield-Point in Steel at Various Temperatures, J. Muir. Roy. Tech. College—Jl., no. 4, Dec., 1927, pp. 14-23, 2 figs. Experiments are described showing yield points observed in simple tension tests made on steel wires electrically heated.

STEEL. The Manufacture of Steel Wire, G. A. Alder. Iron & Coal Trades Rev., vol. 115, nos. 3119 and 3120, Dec. 9 and 16, 1927, p. 862 and 891-892. Deals with modern practice including blueing, wet drawing and annealing. Dec. 16: Patenting; prevention of decarburization; overdrawing not usually cause of failure. Abstract of paper read before Cleveland Instu. Engrs.

News of the Society

MINUTES OF MEETING OF THE BOARD OF DIRECTORS

MT. ROYAL HOTEL, MONTREAL, FEBRUARY 15, 1928

Present

F. G. HUGHES
J. F. HARPER
J. M. WATSON
L. D. HAWKRIDGE
T. E. BARKER
W. H. PHILLIPS
W. H. EISENMAN

Absent

J. H. NEAD
ZAY JEFFRIES

Upon motion by Mr. Harper, seconded by Mr. Hawkridge, and unanimously carried, the minutes of the previous meeting were read and approved.

The first matter for consideration was the report of the Finance Committee presented by treasurer Watson. The Profit and Loss Statement, and balance sheet for 1927 were then presented and ordered filed pending the arrival of the Profit and Loss Statement and balance sheet for 1927 from the auditors.

It was upon motion by Mr. Harper, seconded by Mr. Barker, that these statements were approved as submitted. Auditor's financial statement on page 697 of this issue.

Upon motion by Mr. Barker, seconded by Mr. Watson, the Board of Directors accepted the recommendation of the Finance Committee that the furniture item should be reduced from the present value in the financial statement, to an asset of $500.00.

Upon motion by Mr. Watson, seconded by Mr. Barker, and unanimously carried, the inventory to the amount of $4575.70, as submitted by the Finance Committee, was approved.

Upon motion by Mr. Hawkridge, seconded by Mr. Phillips, and unanimously carried, bad accounts to the amount of $861.79 were written off the books as recommended in the report of the Finance Committee.

Upon motion by Mr. Harper, seconded by Mr. Watson, and unanimously carried, the following three recommendations of the Finance Committee were approved:

1. Reserve for bad accounts—$1000.00.
2. That the present reserve of $10,000.00 for dues paid in advance be increased to $20,000.00.
3. That a reserve fund be set up for the printing of the General Index every 5 years, and that $600.00 annually should be added to this reserve fund for this purpose.

Upon motion by Mr. Watson, seconded by Mr. Harper, and unanimously carried, the recommendation of the Finance Committee that $20,000.00 addi-

tional of the Society's funds should be invested in high grade bonds, was approved, and the Finance Committee was authorized to proceed with the purchase.

Upon motion by Mr. Barker, seconded by Mr. Watson, and unanimously carried, it was recommended that the salary of the secretary be distributed on the following basis:

50 per cent against convention
30 per cent against Society
20 per cent against TRANSACTIONS.

The budget as submitted by the Finance Committee was then presented to the Board and unanimously approved, upon motion by Mr. Watson, and seconded by Mr. Barker. The budget follows:

Proposed Budget for Year 1928

INCOME		
Gross Dues	$ 59,000.00	
Transactions Advertising	52,000.00	
Transactions Sales	1,500.00	
Transactions Subscriptions	1,800.00	
General Index	100.00	
Reprints	1,000.00	
Bindery Account	1,000.00	
Book Account	2,500.00	
Miscellaneous Items	500.00	
Data Sheets and Binders	4,000.00	
Discounts Received	700.00	
Interest	6,000.00	
H. M. Howe Medal Fund Income	212.50	
Extension Division Lecture Courses	10,000.00	
Sustaining Exhibit Membership	6,000.00	
1928 Convention	105,000.00	
		$251,312.50
EXPENSE		
Local Chapters	$ 25,000.00	
Increase of Membership	500.00	
Semi-Annual Meeting	600.00	
Extension Division Lecture Courses	10,000.00	
Transactions	44,900.00	
Reprints	1,500.00	
Bindery Account	1,500.00	
Book Account	2,100.00	
Library	200.00	
Data Sheets and Binders	8,000.00	
Discounts Allowed	600.00	
Miscellaneous Items	1,000.00	
H. M. Howe Medal Fund Expense	25.00	
E. D. Campbell Memorial Lecture	500.00	
General Expense	8,850.00	
Secretary's Office	17,200.00	
President's Office	1,000.00	
Treasurer's Office	5,500.00	
Directors' Expenses	2,000.00	
National Committees	5,000.00	
Reserves	9,837.50	
1929 Convention	500.00	
Western States Metal and Machinery Exposition	5,000.00	
1928 Convention	100,000.00	
		$251,312.50

A progress report was presented on the 1928 Philadelphia Convention and Exposition. It was announced that the American Welding Society and the Institute of Metals would co-operate with the A. S. S. T. in National Metal Week and that an invitation had been extended to the Iron and Steel Division of the American Society of Mechanical Engineers to participate also. The technical program is shaping up very satisfactorily; while the indications were that the requests for space would be in excess of the available footage.

Upon motion by Mr. Hawkridge, seconded by Mr. Harper, the progress report on the Convention and Exposition was accepted.

A progress report was read, accepted, and ordered filed on the Semi-Annual Meeting of the A. S. S. T. to be held in Los Angeles, the week of January 14, 1929. The report showed the Society was receiving splendid assistance and co-operation from the members of the Los Angeles Chapter; important committees had already been organized and many had started to function. The Program Committee under W. H. Laury was completing making contacts with western groups of other technical societies in order to have them assist in the participation of the program and to hold at the same time, if possible, regional meetings of their own societies during the days of the Western Metal Congress and the Western States Metal and Machinery Exposition.

The Santa Fe railroad was selected as the official outgoing road for the special train which is to leave Chicago on January 8, 1929.

Interest in the Western States Metal and Machinery Exposition was reported to be very enthusiastic, and the floor plans which will be ready about April 15, 1928, will undoubtedly have a very cordial reception.

Pursuant with instructions issued by the Board at their December meeting there was prepared and submitted to them figures and costs relative to the publication in bound form of the Data Sheets of the A. S. S. T.

Upon motion by Mr. Harper, seconded by Mr. Eisenman, and unanimously carried, authorization was granted to proceed with the issuing of the HANDBOOK in bound form. The rules and regulations under which the HANDBOOK is to be issued will be as follows:

1. The advertising rate will be $200.00 per page.
   Two page spread—$300.00.
2. The printed HANDBOOK to be available for distribution not later than October, 1928, and to be known as the 1929 Edition.
3. The printed HANDBOOK will be distributed free of charge to all (except) Junior) members in good standing on date of issue and to members joining the Society until the next issue.
4. Each member receiving a copy of the HANDBOOK will give a numbered receipt for the same.
5. That a revised edition of the HANDBOOK will be published for distribution on or about January, 1930.
6. In order for members of the Society to obtain the 1930 edition of the HANDBOOK, it will be necessary for them to return the copy they have in their possession of the 1929 HANDBOOK.
7. Exchange of prior for future editions of the HANDBOOK may be affected by returning the 1929 copy to the National headquarters or by deposit of the prior edition with the chapter secretaries and the new edition will then be mailed directly from the National Office.
8. The sale of the A. S. S. T. HANDBOOK to other than members will be at the price of $7.50.
9. Members losing their HANDBOOK may, upon proper proof of loss, obtain a second numbered copy for $5.00.

10. Junior members may obtain the HANDBOOK at $2.50 per copy, with free exchange privileges during the time they are junior members.

Upon motion by Mr. Harper, seconded by Mr. Watson and unanimously carried the Board instructed the secretary to issue a letter of proper recognition to R. T. Bayless, editor of the TRANSACTIONS for his services in originating the Bayless Plan of exchange of the bound A. S. S. T. HANDBOOK, thereby eliminating the feature that had been insurmountable in all previous plans of distribution of the bound HANDBOOK.

The Board of Directors then met with the Publication Committee which had been in session that day and received a report from them as to their recommendations and activities.

The Board of Directors then met with the Recommended Practice Committee then in session at Montreal for an informal discussion of the work of that committee.

The secretary then reported that Dr. W. H. Hatfield, head of the Brown Firth Laboratories, Sheffield, England, had accepted his appointment as the Edward DeMille Campbell Memorial Lecturer for 1928 and that Dr. Hatfield would further be available for the presentation of talks and lectures before educational institutions and various chapters of the Society.

Upon motion by Mr. Harper, seconded by Mr. Hawkridge, the following heat treating practices were advanced from tentative to recommended practices of the Society:

1. Recommended Practice for the Heat Treatment of 18% Tungsten High Speed Steel—M-3 and M-4.
2. Recommended Practice for the Heat Treatment of Plain Carbon Tool Steels—N-3 to N-6.
3. Recommended Practice for the Heat Treatment of Non-Shrinking, Non-Deforming, Oil-Hardening Tool Steels—N-7 and N-8.
4. Recommended Practice for the Teat Treatment of Finishing Steel—N-9 and N-10.
5. Recommended Practice for the Heat Treatment of Taps and Milling Cutters—N-11 to N-14.
6. Recommended Practice for the Carburizing and Heat Treatment of Cam Shafts—N-19 to N-21.

Upon motion by Mr. Barker, seconded by Mr. Eisenman and unanimously carried, the proposition with reference to group insurance was referred to the Finance Committee.

Upon motion by Mr. Phillips, seconded by Mr. Eisenman and unanimously carried, the suggestion for a proposed change in name from the American Society for Steel Treating to the American Metallurgical Institute was referred to the Constitution and By-Laws Committee so that they might report back to the board the wisdom of the proposal or suggest other names.

Upon motion by Mr. Barker, seconded by Mr. Watson and unanimously carried, it was decided to send out the first notice for dues three months in advance of the expiration of the members' dues; the second notice two months in advance of the expiration of the members' dues; and the third

and final notice one month before the said expiration, and if the members' dues were not paid at the date of expiration, the member should be considered as delinquent and should not receive TRANSACTIONS or Data Sheets or other services from the Society.

Upon motion by Mr. Hawridge, seconded by Mr. Phillips and unanimously carried, it was decided that one year's dues must accompany each application for membership before it can be considered for approval.

The secretary was instructed to notify the chapter executive committees and chairman and secretary of each section, of this new rule of the board in the next monthly chapter letter.

Upon motion properly made, seconded and carried, the meeting adjourned.

Respectfully submitted, W. H. EISENMAN, *Secretary.*

FINANCIAL STATEMENT OF THE AMERICAN SOCIETY FOR STEEL TREATING FOR THE YEAR 1927

The official report of Nau, Taylor & Swearingen, certified public accountants, covering the results of their audit of the books of the society is submitted herewith.

This statement again shows a very healthy condition of our finances, the Society working within its income and making substantial increases to its surplus.

The "Income and Expense Statement" shows a large increase over our 1926 turnover which indicates a substantial increase in the society activities.

Full details of the audited report are herewith given. The official copy of this report is on file at the society offices and is open for the inspection of any interested members.

NAU, TAYLOR AND SWEARINGEN, the certified public accountants who made the audit certify as follows:

"We have audited the books and accounts of the AMERICAN SOCIETY FOR STEEL TREATING for the year ended December 31, 1927, and, in our opinion, the Balance Sheet—Exhibit A, together with the annexed Income and Expense Statement—Exhibit B, and Surplus Reconciliation* correctly present its financial position at December 31, 1927, and a summary of operations for the year then ended, basing the income from dues upon date of cash receipt and other income upon date of accrual irrespective of date of receipt."

NAU, TAYLOR & SWEARINGEN, *Certified Public Accountants.*

EXHIBIT A—Balance Sheet December 31, 1927

ASSETS		
CASH		
The Cleveland Trust Company—Savings Account	$ 7,407.59	
Equity Savings & Loan Company	19,347.55	
The Union Trust Company	10,619.92	
Petty Cash	85.00	
The Cleveland Trust Company—Commercial Account—Overdraft	111.61	$ 37,348.45
INVESTMENTS at Par Value—Schedule No. 1*		104,000.00

*Schedules 1, 2, 3, 4 and Exhibit C are on file at society offices.

ACCOUNTS RECEIVABLE		
Advertisers—Schedule No. 2	3,925.26	
Convention Exhibitors—Schedule No. 3	3,350.64	
Miscellaneous—Schedule No. 4	3,772.19	
	11,048.09	
Less—Reserve for Doubtful Accounts	1,000.00	10,048.09
ACCRUED INTEREST—Investments—Schedule No. 1		1,381.70
INVENTORY—Publishing Supplies, Pins, Buttons and Pencils		4,535.70
FURNITURE AND FIXTURES—Nominal Value per Books		500.00
DEFERRED EXPENSES		
Semi Annual Meeting—Montreal	145.55	
1928 Convention	234.12	
Western Metal Exposition	203.27	582.94
TOTAL ASSETS		$158,396.88
LIABILITIES, RESERVES AND SURPLUS		
Chapters' Share of Dues	2,033.67	
Extension Division Lectures	979.42	
Reserve for Dues Paid in Advance	20,000.00	
Permanent Convention Reserve	20,000.00	
Reserve for Publication of General Index	600.00	
H. M. Howe Medal Fund	5,000.00	
Surplus—Exhibit C	109,783.79	158,396.88

EXHIBIT B—Income and Expense Statement Year Ended December 31, 1927

INCOME		
Advertising—Transactions and Convention Program	$ 51,328.18	
Membership Dues—Gross	54,221.87	
Exhibitors' Space—Detroit Convention	84,926.25	
Special Service to Exhibitors—Convention	26,831.95	
Exhibitors Sustaining Membership	6,850.00	
Admissions—Convention	2,967.75	
Exhibitors' Badges and Banquet—Convention	1,945.00	
Magazine Sales and Subscriptions—Transactions	2,972.80	
Bindery Sales	1,107.49	
Pins and Buttons Sales	33.00	
Pencils Sales	36.25	
Data Sheet Sales	5,433.37	
Data Sheet Binder Sales	1,796.60	
Book Sales	2,412.43	
Extension Division Income	11,870.00	
Reprint Sales and Miscellaneous Income	4,810.42	
General Index Sales	479.40	
Discount on Purchases	739.13	
Interest Earned—Schedule No. 1	5,354.39	
Interest Earned on H. M. Howe Medal Fund—Schedule No. 1	212.50	
Total Income		$266,328.78
EXPENSES		
Dues Returned to Chapters	22,390.43	
Support of Chapters	1,031.56	
Increase of Membership	76.15	
Reprints	2,220.06	
Bindery Expense	1,087.06	
Books	2,071.59	
Pencils	37.83	
Pins and Buttons ..... Credit $6.30		
Library Expense	224.48	
Discount Allowed	622.58	
Bank Exchange	1.42	
H. M. Howe Medal Fund Expense	551.60	
E. D. Campbell Memorial Lecture Expense	566.19	
Telephone and Telegraph—General	522.01	
Rent—General	2,775.00	
Postage—General	2,291.76	
Office Supplies	924.71	
Stationery	1,197.56	
Convention Expense	380.86	
Collection and Legal Expense	514.56	
Insurance	511.06	

Reduction in Value of Furniture and Fixtures		6,713.75
Reduction in Value of Bonds—Cost to Par Value—Schedule No. 1		218.75
Provision for Bad Accounts		1,346.74
Transactions		
Printing	$ 15,303.69	
Paper and Cover Stock	7,998.68	
Cuts	2,851.69	
Postage	1,527.36	
Editor's Salary	5,549.91	
Editorial Assistance	2,335.00	
Editor's Traveling Expense	448.40	
Clerical Salaries	1,591.50	
Advertising Commissions	114.00	
Wrapping	299.10	
General Index—Current Issue	1,465.06	
General Index—Provision for Expense of Next Issue	600.00	
Executive Salary	2,833.76	
Miscellaneous Expense	221.12	43,139.27
Data Sheets		
Printing	1,327.85	
Paper Stock	309.03	
Editor's Salary	2,099.92	
Clerical Salaries	810.00	
Postage	556.28	
Binders	1,323.10	6,426.18
Secretary's Office		
Executive Salary	4,532.99	
Assistant Secretary's Salary	6,000.00	
Clerical Salaries	3,240.20	
Traveling Expense	3,199.13	
Miscellaneous Expense	1,450.33	18,422.65
President's Office		
Traveling Expense	1,028.24	
Miscellaneous Expense	54.05	1,082.29
Treasurer's Office		
Bookkeeper's Salary	4,112.50	
Auditing Service	410.00	
Miscellaneous	105.65	4,628.15
Director's Expense		
Traveling Expense	2,173.63	
Miscellaneous Expense	864.54	3,038.17
National Committees		
Salaries	2,099.92	
Recommended Practice	1,495.60	
Finance	221.99	
Nominating	5.20	
Publication	954.45	
Constitution and By-Laws	56.33	4,833.49
Sectional Meetings		
Milwaukee	427.30	
Washington	695.97	1,123.27
Extension Division		11,325.72
Detroit Convention		
Executive Salary	3,966.58	
Advertising	11,019.53	
Rent	10,325.00	
Special Services	23,866.99	
Office and Traveling Expenses	17,391.76	
Exhibit Expense—Other Items	15,401.94	81,971.80
Total Expenses		224,262.40
Balance—Carried to Surplus Account—Exhibit C		42,066.38
TOTAL		$266,328.78

News of the Chapters

SCHEDULED MEETING NIGHTS OF CHAPTERS

For the convenience of visiting members, those chapters having scheduled meeting nights are listed below.

BOSTON—First Friday, H. E. Handy, secy., Saco-Lowell Shops, Lowell, Mass. Phone, Lowell 4050.

Apr. 6—Pyrometry ..... V. O. Homerberg
May 4—Stainless Iron and Stainless Steel..... V. O. Homerberg

BUFFALO—Fourth Friday. F. L. Weaver, secy., American Radiator Co., Bond Plant. Phone, Riverside 1770.

CANTON-MASSILLON—No schedule of meetings as yet received. Robt. Sergeson, secy., Central Alloy Steel Corp., Canton, Ohio. Phone 5121.

CASE GROUP—No schedule of meetings as yet received. J. M. Burns, secy., Case School of Applied Science, Cleveland. Phone, Garfield 6680.

CHICAGO—Second Thursday, with exception of March 6. J. A. Comstock, secy., Room 1724 Peoples Gas Bldg. Phone, Wabash 6000, Local 364.

Apr. 12—Manufacture of Cold Drawn Steel ..... F. R. Bonta

CINCINNATI—No schedule of meetings as yet received. W. J. Lange, secy., Robert J. Anderson, Inc.

CLEVELAND—Third Friday. J. S. Ayling, secy., Case Hardening Service Co. Phone, Atlantic 0293.

Apr. 20—Metal Stamping ..... G. L. Kelley
May 18—Social Meeting.

COLUMBUS—Third Tuesday, with exception of Feb. 14. G. D. Moessner, secy., Buckeye Steel Castings Co. Phone, Garfield 0600.

Apr. 17—Forgings ..... Harold Wood
May 15—Open-Hearth Practice ..... W. R. Flemming

DAYTON—No schedule of meetings as yet received. F. M. Reiter, secy., Dayton Power & Light Co.

DETROIT—Third Monday. Jos. G. Gagnon, secy., Hudson Motor Car Co. Phone, Lenox 3232.

FORT WAYNE—Paul Renfrew, secy., S. F. Bowser & Co. Phone, Harrison 2341.

Apr. —Nickel-Chromium Alloy in Gray Iron ..... D. M. Houston
May —Shop Equipment and Shop Kinks ..... H. B. Northrup

GOLDEN GATE—Second Wednesday. S. R. Thurston, secy., Bethlehem Shipbuilding Corp., San Francisco.

Apr. 11—Joint Meeting with the American Welding Society—Subjects: Properties of Welds at High Temperature..... K. V. Laird
Properties of Carbon and Alloy Steels at High Temperatures.
May 9—The Hardness of Metals, Methods of Testing and What They Test. Comparison of the Wear Resistance of Different Metals Under Different Conditions of Heat Treatment.
June 13—Heat Treatments of Nonferrous Alloys, Their Purpose and Their Significance.
Moving Picture—The Story of Copper.

HARTFORD—Second Tuesday. Henry I. Moore, secy., Firth Sterling Steel Co. Phone, 6-5554 Hartford.

Apr. 10—Manufacture of Automotive Alloy Steels ..... E. C. Smith
May 8—Manufacture of Malleable Iron..... H. A. Schwartz
June 8—Eighth Annual Banquet.

INDIANAPOLIS—Second Monday. James S. Marlowe, secy., 606 State Life Bldg. Phone, Riley 3724.

LEHIGH VALLEY—No schedule of meetings as yet received. H. V. Apgar, secy., Ingersoll-Rand Co., Phillipsburg, N. J. Phone 977.

LOS ANGELES—Second Thursday. H. V. Ruth, secy., Ducommun Corp. Phone, TR. 0621.

MILWAUKEE—Second Monday. Knight Charlton, secy., Bucyrus Co. Phone 1.

MONTREAL—No schedule of meetings as yet received. D. G. MacInnes, secy., Apt. 35, 376 Claremont Ave., Westmount, Montreal.

NEW HAVEN—Second Thursday, with the exception of June 15. F. E. Stockwell, secy., Standard Oil Co. of New York. Phone, Beacon 1520, Pioneer 9940.

Apr. 12—High Speed Steel .....J. P. Gill
May 10—Place of Nonferrous Metals in Industry.....
.....W. G. Price and Alvan L. Davis
June —Annual Frolic—Details and date will be announced later.

NEW YORK—Second Monday. I. N. Holden, Jr., secy., E. W. Bliss Co. Phone, Sunset 9000.

NORTH-WEST—No schedule of meetings as yet received. Alexis Caswell, secy., Manufacturers' Assn. of Minneapolis.

Apr. —Molybdenum Steels .....Dr. F. C. Langenberg
May —Gears and Gear Steel .....E. C. Smith

NOTRE DAME—Second Friday. Frank J. Mootz, secy., Notre Dame University. Phone, Lincoln 1121.

PHILADELPHIA—Last Friday. A. W. F. Green, secy., 407 Shoemaker Rd., Elkins Park, Pa. Phone, Melrose 4542-M.

Apr. 27—General Melting Practice, Influence of Crystallization and Cooling on the Commercial Application of Metals.

PITTSBURGH—First Thursday. H. L. Walker, secy. Box 521, North Side Station.

RHODE ISLAND—Third Wednesday. C. G. Peterson, secy., 100 Weybosset St., Providence. Phone, Gaspee 6233.

ROCHESTER—Second Monday. Irving C. Mathews, secy., Eastman Kodak Co. Phone, Glenwood 1300.

Apr. 9—Die Castings .....Sam Tour
May 14—Business Meeting—Election of Officers

ROCKFORD—Second Friday. O. T. Muehlemeyer, secy., 700-702 Race St. Phone, Forest 447.

SCHENECTADY—Third Tuesday. J. G. Hicks, secy., American Locomotive Co. Phone, 2-4900-Ext 44.

SOUTHERN TIER—Third Monday, with exception of Apr. 23. Walter H. Odgen, secy., 617 Peoples Trust Building, Binghamton, N. Y. Phone, 7754.

SPRINGFIELD—Third Monday, with exception of Mar. 21, Apr. 25 and May 23. E. L. Woods, secy., Springfield Gas Light Co. Phone, 5-3900.

ST. LOUIS—Third Friday. C. C. Werscheid, secy., Colonial Steel Co. Phone, Garfield 1263.

SYRACUSE—Second Tuesday. S. P. Peskowitz, secy., Halcomb Steel Co. Phone, 3-1231.

Apr. 10—Flow of Metals in Forging .....J. H. Nelson

TORONTO—No schedule of meetings as yet received. A. Lowry, secy., 450 Willard Ave.

TRI CITY—No schedule of meetings as yet received. George A. Uhlmeyer, secy., People's Power Co., Moline, Ill.

WASHINGTON-BALTIMORE—No schedule of meetings as yet received. H. K. Herschman, secy., Bureau of Standards.

WORCESTER—No schedule of meetings as yet received. C. G. Johnson, secy., Worcester Polytechnic Institute. Phone, P110.

STANDING OF THE CHAPTERS

DURING the month of February there were 138 new and reinstated members, while 96 were lost through arrears, resignations and deaths, leaving a net gain for the month of 42 members. The total membership of the Society on March 1, 1928, was 4935.

Membership standing of the society as of March 1, 1928, is as follows:

GROUP I		GROUP II		GROUP III	
1. Detroit	470	1. Hartford	139	1. Tri City	86
2. Chicago	446	2. Dayton	137	2. New Haven	86
3. Pittsburgh	374	3. Milwaukee	120	3. Washington	78
4. Philadelphia	328	4. Golden Gate	118	4. Worcester	77
5. Cleveland	319	4. Los Angeles	118	5. Rockford	66
6. New York	301	6. Lehigh Valley	114	6. Columbus	60
7. Boston	265	7. Canton-Mass.	111	7. Providence	57
		8. St. Louis	102	8. Rochester	54
		9. Indianapolis	100	9. Toronto	51
		10. Cincinnati	96	10. Southern Tier	50
		11. Syracuse	86	11. Schenectady	44
		12. Montreal	73	12. Fort Wayne	41
		13. Buffalo	69	13. Springfield	37
		14. North-West	54	14. Notre Dame	27

Five chapters, Chicago, Cleveland, Detroit, Philadelphia and Pittsburgh had gains of 10 members or more. This was offset in most instances by losses from arrears, Detroit leading with 19; Pittsburgh second with 10; Chicago third with 9.

GROUP I—Detroit still has first place in this group, although suffering a loss of 13 last month. Pittsburgh, Cleveland and Boston with net gains of 3 each retain their same positions, while Chicago had a net gain of 1, New York keeping the same number as last month.

GROUP II—Hartford with a gain of 4 still holds position 1 with Dayton just 2 members behind. Los Angeles, the new member in this group with a net gain of 6, goes into a tie for 4th place with Golden Gate, having a total of 118. St. Louis with a splendid gain of 7 new members has now passed the century mark and also stepped ahead of Indianapolis who suffered a loss of 4. Montreal with a net gain of 5 advanced from 13th to 12th position. In this group 2 chapters showed gains of from 1 to 7 members each; two remained the same and 4 had losses.

GROUP III—New Haven with a nice gain of 5 goes into a tie with

Tri City for first place with 86 members. The only other change in position in this group was Schenectady with a gain of 3 which advanced from 12th to 11th position. In this group 7 showed a gain of from 1 to 5; 5 remained as of last month, and 2 showed a loss.

BOSTON CHAPTER

The February meeting of the Boston Chapter was held at Massachusetts Institute of Technology on Friday, Feb. 3, 1928. The usual dinner was held at Walker Memorial after which Dr. E. J. (Eddie) O'Brien, eminent Cambridge surgeon, and nationally known football referee, gave a humorous talk on his football experiences. The gist of his talk was that "it matters not whether you win or lose, it's how you play the game." The Chapter is indebted to Harry West for the pleasure of Dr. O'Brien's presence at the February dinner.

The principal speaker of the evening was Dr. Robert S. Williams, Professor of Metallography at Massachusetts Institute of Technology, and Chairman of the Boston Chapter Program Committee. Dr. Williams' subject was "Practical Metallography" and it constituted the 15th lecture of the Boston Chapter Metallurgical Course. He described the method of constructing the alloy diagram and explained the use of the microscope in alloy studies. The attendance was 140. *H. E. Handy.*

Boston Chapter Educational Course

Twelfth Lecture—"Physical Properties of Metals and Methods for Determining Them" was the subject of Professor Cowdrey's talk on January 13 of Lecture 12, Boston Chapter Educational Course. Definitions of the different properties of metals and a detailed explanation of them was followed by an actual demonstration of physical testing in the laboratories of Massachusetts Institute of Technology.

Not many of those present were familiar enough with the modulus of elasticity to visualize the fact that two pieces of steel of the same section, one with a tensile strength of fifty thousand pounds and the other with 150,000 pounds per square inch, when subjected to a given tensile stress, will both elongate the same amount, provided the elastic limit of neither is exceeded.

Thirteenth Lecture—The 13th lecture of the course was devoted to hardness testing and repeated stress. The scleroscope, Brinell and Rockwell were the principal instruments discussed although the Brinell Meter, the Herbert and others were mentioned. In discussing the above types of machines Prof. Cowdrey stated that the scleroscope was falling into disfavor while the Rockwell was gaining popularity fast and he thought it might sometime replace the Brinell as the standard of hardness. A blueprint showing the relation between Brinell and Rockwell hardness was distributed with the notes, it being a copy of the one appearing in Professor Cowdrey's paper given before the Boston Convention in 1924.

Describing the fatigue limit as the stress which may be repeatedly imposed an unlimited number of times without producing fracture, the speaker proceeded to describe the methods of Dalby and of Moore for producing the

stress repetitions. He stated that a stress which fails to produce rupture after 10,000,000 repetitions is held to be within the fatigue limit.

Fourteenth Lecture—"Choosing the Testpiece" was the subject of the lecture on January 27, 1928. Stating that destructive tests must be made by proxy, Professor Cowdrey explained the standard methods of preparing test specimens so that they will be truly representative of the actual conditions to which the parts themselves are subjected. Test pieces for plate, forgings and castings were discussed. The results of the tests may be affected by the shape of the test piece. It is essential to maintain the ratio of length to diameter (1:4 for the standard 0.505 specimen). A change in this ratio greatly affects the per cent elongation. A steel giving 30 per cent elongation in 8 inches may show 50 per cent in 2 inches. It has been shown (Dalby) that if the specimens are geometrically similar the results of tests are harmonious. If the specimen becomes very short the tensile strength is also changed for ductile materials, due to restriction of flow.

When the length of the test piece approaches zero (grooved specimen) there will be almost no chance for readjustment of the grains. The fracture is then constrained largely to the grain boundaries and the result is a fracture of granular texture even with material which normally breaks with a cup and cone fracture. Grooved specimens show an augmented tensile strength. Rivet steel may have its tensile strength increased 50 per cent by grooving the test piece. The elongation then becomes practically zero.

The 14th lecture finished Prof. Cowdrey's very interesting series of talks on physical testing and he was given an enthusiastic rising vote of thanks.

H. E. Handy.

The March meeting of the Boston Chapter was held at Massachusetts Institute of Technology on Friday, March 2, 1928, dinner being served in Walker Memorial at 6:30 p. m. to about seventy members and guests.

Immediately following dinner Dr. Robert S. Williams, Professor of Metallography at Technology, presented the 19th lecture of the Educational Course, his subject being "The Hardening of Steel". He described in detail, with illustrations, the hardening, quenching, tempering, toughening and spheroidizing of steel and touched briefly on temperature measurement.

The guest speaker of the evening was William S. Bidle of Cleveland, past president of the American Society for Steel Treating, and heat treater "Extraordinary," who addressed the Chapter on "Troubles of the Practical Heat Treater". Bill is well known to the Boston members and was enthusiastically received. His talk, which was made up wholly of his thirty years of heat treating experiences, was very much enjoyed by his audience. The attendance was about 125.

H. E. Handy.

CHICAGO CHAPTER

The January meeting of the Chicago Chapter was held at the City Club, Thursday evening, January 12, with a total attendance of about 225 members and guests.

The speaker of the evening, H. E. Harding, associate chemist, Bureau of Standards, Washington, gave a most interesting paper on the subject of

"Chrome Plating", bringing out in detail, the qualities of chromium plate, the plating process and many practical applications. Following Mr. Harding's paper, a very lively discussion ensued.

The February meeting of the Chicago Chapter was held at the City Club, February 9, with a total attendance of approximately 250 members and guests.

The program consisted of the showing of motion pictures, which gave a very interesting detail of the manufacture of the new Ford, Model "A", automobile.

The speaker of the evening was John L. McCloud, metallurgist of the Ford Motor Co., whose subject was "Steel for the Ford Industries; Its Selection and Treatment". Mr. McCloud gave a very detailed review upon the application of the various types of Ford standard steels used in the various Ford products. After the close of Mr. McCloud's paper, a very interesting discussion followed, which was lively, and long, touching upon many phases of the subject.

The March meeting of the Chicago Chapter was held Tuesday evening, March 6th, at the City Club, the American Institute of Mining and Metallurgical Engineers, collaborating with the Chicago Chapter. The "Oriental Male Quartet" entertained the 125 members and guests during dinner.

The speaker of the evening, Dr. Paul D. Merica, Director of Research, International Nickel Company, presented a very interesting talk upon the subject of "The Use of Alloys in Gray Iron". Dr. Merica described with the use of lantern slides how the effect of alloys, particularly nickel and chromium, may be utilized in a practical manner by foundries in producing gray iron castings of substantially improved properties, at a minimum cost. At the conclusion of Dr. Merica's talk, a very interesting discussion followed.

At this meeting the Chicago Chapter was honored by the presence of a number of men who have contributed much to the success of the Society. They were: past presidents, F. P. Gilligan and J. Fletcher Harper; past directors, R. G. Guthrie, Hyman Bornstein and Samuel M. Havens.

A. M. Steever.

CINCINNATI CHAPTER

The February meeting of the Cincinnati Chapter was held on February 8, 1928, at the Cincinnati Engineers' Club. R. S. Cochran of the Surface Combustion Company was the speaker of the evening, his subject being, "The Gas Furnace as Applied to the Heat Treatment of Steel". Mr. Cochran discussed in a most interesting manner principles in the design of gas-fired furnaces, and emphasized the ease with which close automatic temperature control, even furnace temperatures, and proper furnace atmosphere can be obtained with modern gas-fired equipment.

R. O. McDuffie of the University of Cincinnati spoke briefly on the subject of "Cementite," this being the second of a series of ten minute talks on the microconstituents of steel.

The regular March meeting of the Cincinnati Chapter was held at the Engineers' Club on March 1, 1928. For the educational feature of the meeting

Dr. George M. Enos of the University of Cincinnati gave a ten minute talk on the subject of "Pearlite" in which he emphasized the influence on the properties of steel of the different forms in which pearlite may occur.

The main talk of the evening was given by Mr. John Howe Hall of the Taylor Wharton Iron and Steel Company, his subject being "Manganese Steel".

Mr. Hall first reviewed the early history of the part played by manganese in the steel industry, beginning with Mushet's work on the deoxidation of Bessemer steel with manganese, and describing the discovery of austenitic manganese steel by Sir Robert Hadfield. He then discussed the structure and properties of this interesting alloy, pointing out both its uses and limitations.

The talk was illustrated with numerous lantern slides and also by a moving picture, which showed a tractor equipped with manganese steel treads working successfully in some extremely rough country.

CLEVELAND CHAPTER

The regular meeting of Cleveland Chapter American Society for Steel Treating was held in the Cleveland Engineering rooms, Carnegie Hall, February 17. This meeting will go down in the records as probably the most popular session yet held.

The speaker, Thomas Ferry, delivered a very practical talk on the, manufacture of screws and bolts, outlining his experience from the beginning and carrying on through to present practice. The talk was supplemented with movies taken about the plant showing various machines and methods of production.

The meeting was preceded in the afternoon by a visit to the plant of The Ferry Cap & Set Screw Co. The extreme interest in this industry was evidenced by the fact that nearly 150 members and guests availed themselves of the opportunity to inspect the plant. Mr. Ferry proved himself an excellent host, providing smokes and extending every courtesy to his visitors.

Just preceding the meeting dinner was served to about 150 members and guests. This was followed by a short entertainment.

About 200 members and guests were present to hear Mr. Ferry talk and a number of questions were discussed.

The question box feature handled by C. G. Shontz created a lively discussion. Send in your questions so they can be answered at the next meeting.

J. S. Ayling.

COLUMBUS CHAPTER

The Columbus Chapter held its regular monthly meeting Tuesday evening January 17, 1928 at the Fort Hayes Hotel. The meeting was preceded by a dinner which was very well attended by the members. The attendance at the meeting was 142, which is very gratifying to the officers of this chapter.

At 8 o'clock the speaker of the evening, Mr. Sandine of the Norton Co. was introduced. He gave a few preliminary remarks about the motion picture "The Age of Speed", which was produced by the Norton Co. The film consisted of four reels of very interesting pictures depicting the many wide uses

to which grinding wheels are put. The picture shows the grinding of auto parts, edge tools, farm implements and the grinding of pulp for newsprint, it also shows the manufacture of grinding wheels and abrasives.

Following the showing of the pictures a very lively discussion took place, Mr. Sandine answering all the questions very satisfactorily. The meeting was adjourned with a rising vote of thanks to Mr. Sandine and the Norton Co. for this very enjoyable evening.

G. D. Moessner.

DAYTON CHAPTER

The regular February meeting of the Dayton Chapter was held jointly with the Engineer's Club of Dayton on Monday evening, February 20th. Three hundred members of these two technical organizations assembled to hear Dr. H. H. Lester, research physicist of the U. S. Army Ordnance Department, Watertown Arsenal, talk on "X-ray Studies of Materials".

Doctor Lester's lecture was one of the most interesting that Dayton's engineers have had the opportunity of hearing. It was divided into two parts; in the X-ray for the detection of defects in metals, especially in steel castings, and the use of the method of examination for the improvement of foundry technique. This part of the lecture was illustrated by slides showing typical flaws. From these Doctor Lester outlined the method of diagnosing and tracing the cause of these defects.

The second part was an elementary outline of crystallography of the ultimate structure of metals. Doctor Lester stressed the importance of this structural analysis and how it could be correlated with high power metallography in advancing our knowledge of engineering materials. He told his audience that what we need is not more new steels and other engineering materials, but a better knowledge of the ones we already use. One of the most important things to be attained was to secure a correlation of properties and structure, in other words if possible we should be able to predict our properties and tie them up with the results of our X-ray and metallographic examination.

The discussion that followed the talk lasted until a late hour.

F. T. Sisco.

DETROIT CHAPTER

The regular monthly meeting of the Detroit Chapter was held at the General Motors Building, Detroit, Monday, February 20, 1928. Immediately following the usual dinner, George V. Brown, president of the Wayne County Medical Association, Detroit, gave a talk on "Heredity", illustrated with slides. The meeting was officially called to order at 9:00 P. M.

The speaker of the evening was J. A. Succop, of the Heppenstall Forge and Knife Co., Pittsburgh, who spoke to us on "Die Blocks," Mr. Succop had five reels of motion pictures showing the activity of the Pittsburgh and Bridgeport plants and the Detroit warehouse of the company which he represents. The first three reels covered general activities and the last two were "The Story of a Die Block." The showing of these films was supplemented by Mr. Succop's talk on the manufacture of miscellaneous forgings, shear knives and die blocks. These films and the explanations

given, gave a very clear story of the manufacture of die blocks. Mr. Succop was given a rising vote of thanks.

At this meeting, the following members were elected for the nominating committee: H. M. Northrup, chairman, G. A. Webb, J. A. Howland, C. J. Tobin, and C. P. Richter. The meeting adjourned at 10:05 P. M.

J. G. Gagnon.

GOLDEN GATE CHAPTER

A special meeting was held at the Athens Athletic Club, Oakland, Wednesday, February 17, 1928. This meeting had been arranged by vice-chairman S. Craig Alexander to substitute for the postponed Stanford meeting.

The usual excellent dinner was served just prior to the meeting, which was called to order by vice-chairman Alexander at 8:00 P. M.

Three movie films were offered for the first part of the evening's entertainment. The first, "Beyond the Microscope"—an animated film, portrayed in a very striking manner the modern conception of matter.

The second film, "The Moulders", was interesting and instructive in that it showed real production as carried out at one of the General Electric Co. foundries.

The third, a two reel film, depicted the radio complete—from sending station to loud speaker.

It would be impossible in the space alloted to begin to describe the ingenuity either of the brain that conceived, or the applied technique that made possible the three above mentioned movies.

The illustrated talk by E. E. Fess of the American Rolling Mills, on "High Chromium Ferrous Alloys" was, to say the least, interesting and entertaining although perhaps to some of us, just a trifle high-brow—or a better term might be "somewhat involved".

The iron-chromium-carbon diagram as developed by Honda and his coworkers was made use of to simplify the discussion. The micrographs indicating the different constituents at various temperature intervals threw considerable light on why these high chromium alloys are heat resisting.

It was interesting to note that during the transformation, in some instances gamma iron was entirely slighted, the transformation being for alpha to delta direct.

H. J. Barton, metallurgist of Earle M. Jorgensen Co., Los Angeles, made a few remarks relative to the "Western Metal Congress" to be held in Los Angeles, January 1929. Mr. Barton was enthusiastic.

The Hartford two color identification tag method was used with effect it is thought.

Thirty-three attended the dinner and approximately a dozen and a half more showed up for the meeting.

S. R. Thurston.

Golden Gate Chapter held its March meeting Wednesday, the 14th, at the Athens Athletic Club, Oakland.

During the dinner which preceeded the meeting, the communication from the National Office regarding the new procedure for dues, and the excellent method adopted by the National Directors for the replacement of the data

sheets by an annual handbook was read and discussed—not cussed—We approve.

S. Craig Alexander presided at the meeting and introduced Professor G. E. Troxell of the University of California as the speaker. Professor Troxell had chosen for his subject "The Physical Properties of Steel, their significance and their relations.

The Professor discussed at some length the stress-strain diagram in tension and compression. He pointed out by aid of a blackboard and slides how such values as proportional and elastic limits, yield point, ultimate strength, reduction of area and elongation are obtained, and how their values are affected and altered by the chemical analysis, heat treatment and cold work. The Professor also showed why, at times, it becomes necessary to sacrifice one or more of these properties in order to enhance other values the better to enable the member to withstand the particular stresses to which it may be subjected.

The method of making and the value of the Charpy and Izod impact tests were also explained and commented upon in some detail, showing how the residual foot pounds gave an indication of impact resistance of the specimen.

The rotating beam and other forms of fatigue testing were made quite clear by aid of slides, which brought out the fact that if the load was sufficiently reduced the cycles could be continued up to several million or even billions indicating an indefinite working life of the material under test. However, by increasing the load the metal would fail with a relatively few number of cycles.

The methods of hardness testing and the Rockwell, Brinell and scleroscope numbers were explained.

To both Prof. Troxell and Ivan Johnson, factory manager and metallurgist of the Best Steel Casting Company, who arranged the meeting, the Chapter is duly grateful for an instructive and enjoyable evening.

Thirty-four (34) attended the dinner and a dozen or so more the meeting.

S. R. Thurston.

HARTFORD CHAPTER

Hartford Chapter held its annual Question Night at its regular meeting on February 14, which was held at the Hartford Electric Light Club Auditorium at 266 Pearl Street, Hartford, Conn.

Questions had been sent to the secretary during the month of January and these were published in advance of the meeting. The range of subjects covered results of noise tests of finished ground gears and the effect that heat treatment had in producing different sounds. Another subject was the necessity of double quenching chromium ball steel to obtain the best results. The explanation of internal strains which caused change in shape in finished ground work was requested. These subjects created a considerable amount of discussion and many of the hundred members and guests who attended, participated actively in the talks throughout the evening. While some answers were given which offered some explanation of the various conditions affecting some of these questions, there seems to be difficulty in obtaining very specific answers to questions which are presented at a meeting

of this kind. As a rule, the type of question is pretty deep and when the conditions are not fully explained, there is always some important point in the question which is omitted.

Another difficulty arising on Question Night is that people who send in questions do not attend the meeting or, if they are at the meeting, show unwillingness to rise and offer further information or state whether the question is satisfactorily answered.

Preceeding the question, W. E. Steinreich, metallurgist of the Meriden Plant of the New Departure Manufacturing Company, gave a practical talk on the subject of a "Method of Preventing Scaling while Hardening certain Tool Steel Components." Mr. Steinreich explained that he had been using boric acid successfully to prevent scaling. There was some talk along this line from other members who have been using this same method and this talk was one of the best practical talks that the chapter has had this year.

There were five or six members attending the meeting who were planning to take a later train to attend the Semi-Annual National Society Meeting in Montreal.

A plea for more permanent members was made by the writer in the absence of the Chairman of the Membership Committee. *R. Stanton.*

INDIANAPOLIS CHAPTER

February 13, 1928, W. H. Wills, Metallurgist, for the Atlas Steel Corp., Dunkirk, N. Y., addressed our chapter on, "Nature and Uses of the Principal Types of Tool Steels." Mr. Wills covered this subject very thoroughly, showing slides of structures and tools covering the five principal groups of tool steels.

We had discussion of the subject lead by Professor John Keller of Purdue University and E. J. P. Fisher, metallurgist, Diamond Chain & Mfg. Co., and many interesting points were brought out in this discussion.

At this meeting Mr. Fisher informed us of a course in metallurgy that he was willing to present to anyone desiring to take advantage of it, and twenty enrolled for the course, which covers ten lessons.

In addition to local members present we had eight out of town guests, a total of attendance of ninety-six.

The Indianapolis Chapter has placed in operation a short course of study in the metallography of steel which will be given in ten weekly lectures, the first of which was attended by 55 members and non members of the Society on Wednesday evening, February 29, at the Indianapolis Chamber of Commerce.

This course covers the application of the science of metallography to the mechanical and thermal treatment of iron and steel. The metallography of steel will be presented by the instructor from the theoretical, engineering and production angles. The course is designed to inculcate in the minds of the students the basic laws of metallography in such a manner that they may be used by the students in the solution of problems arising in their special fields of steel treatment and fabrication.

This course will not include the study of the metallurgy of steel manu-

facture, excepting those points which have a direct bearing on the physical and chemical properties of steel in the process of fabrication.

The first hour of each weekly meeting will be devoted to a lecture, while immediately following the lecture hour, the meeting will be open to questions and free discussion, followed by a review of the subject matter of the previous meetings.

All students will receive a complete set of printed lecture notes and a set of 48 representative photomicrographs of steel structures, thus facilitating the lecture work and enabling the students to review the lecture subject matter at home.

The instructor for the course is Edward J. P. Fisher, graduate of the Worcester Polytechnic Institute and post graduate student in metallurgy and metallography at the Columbia University School of Mines. Mr. Fisher has been active treasurer of the Indianapolis Chapter, and is at present engaged as research metallurgist with the Diamond Chain & Manufacturing Company. Harry J. Green, chemist of the Diamond Chain & Manufacturing Company and also a member of the Society, and Miss Galey of the engineering department of the same company, are co-operating with Mr. Fisher in the preparation of the material for the lecture notes and photomicrographs.

LEHIGH VALLEY CHAPTER

A very successful meeting of the Lehigh Valley Chapter was held in Reading, Thursday, Feb. 23, 1928, at the American Legion Hall and took the general form of a smoker. A buffet luncheon was served at 6:30 P. M., followed by a general get-together of members and guests. The technical part of the meeting opened at 7:30 o'clock, with four speakers on the program. The topics were diversified so as to stimulate general interest in the meeting.

F. C. Daniels of the Bethlehem Steel Co. spoke first on "The Manufacture and Application of Iron and Steel Castings". This talk was followed by a very interesting paper by B. F. Shepherd of the Ingersoll-Rand Co. on "Some of the Phenomena Encountered in the Case-Hardening Process". F. R. Palmer of the Carpenter Steel Co. gave a very instructive talk on "The Quenching of Tool Steel". He was followed by Prof. Wm. S. Lohr of Lafayette College who had as his topic "Fundamentals of Engineering Test Materials".

A lively discussion led by Chairman L. J. McGregor followed each talk. The meeting closed with an explanation by Mr. McGregor of the character and purposes of the Society and an invitation to non-members present to enter the fold.

The meeting was attended by 125 members and guests representing a large area of Eastern Pennsylvania, including Phillipsburg, Easton, Bethlehem, Allentown, Harrisburg, Lebanon, Birdsboro and Philadelphia. In view of the success of this meeting, it was decided in the future to hold one meeting a year in Reading. Arrangements for this meeting were under the direction of F. R. Palmer.

G. V. Luerssen.

LOS ANGELES CHAPTER

The February meeting of Los Angeles Chapter was held Thursday evening, February 9, in the banquet room of the Los Angeles Creamery Co., at 6:30 P. M. There was a very excellent number of members and friends at the meeting.

The first thing to take the attention of the crowd was a real dinner. The dinner was enjoyed by everyone, especially did Jim Knapp and Joe Cooke enjoy it.

The speaker of the evening was our own good member W. W. Farrar, of E. F. Houghton Co. Bill had for his paper "Salts". The talk was given primarily to explain the various types of salts used in connection with the hardening and drawing of steel. However some information was given on common table salts, smelling salts, bath salts, quenching salts and the well known Epsom salts.

Comparisons were drawn between the various heating salts and lead. Some information was given regarding melting temperatures of the more common salts and some of the difficulties encountered in the manufacture of salts, such as overcoming impurities and moisture conditions. The differences between neutral salts, that is, salts that will not carburize nor decarburize, salts that contain percentages of cyanide for producing surface hardness; salts which give slight decarburization, and various uses of the different grades of salts for hardening and drawing were explained by using illustrations of actual installations.

It was brought out that cracking and warping were materially reduced by the use of salts, where these troubles are caused by ununiform heating

There was a long and interesting discussion following Bill's paper. We all enjoyed it very much, and Bill gave us much valuable information.

Following Bill's paper and the interesting discussion, Joe Cooke of Columbia Steel Corporation gave some interesting facts about their mills, and answered many questions on their practices at the Torrance Plant. We are always glad to have Joe speak for he always gives us so much information.

H. V. Ruth.

The March meeting of Los Angeles Chapter was a red letter event! The meeting was held at the usual place, the banquet room, at Twelfth and Towne Streets, Los Angeles. Dinner was served at 6:30 p. m. There were about one hundred and twenty-five members and guests present at dinner.

Through the kindness of Denman & Grier Steel Company we had some excellent entertainment during the dinner hour.

Following the dinner hour the several committee chairmen reported on the activities of their respective committees. Everyone was very pleased with the reports of the men working on the coming convention. It was thrilling to learn how swiftly and thoroughly these men are planning and working.

The speaker of the evening was Dr. N. B. Hoffman, metallurgist for the Colonial Steel Company of Pittsburgh. Dr. Hoffman gave an illustrated paper on "A Discussion of the General Metallurgical Terms as Applied to both Carbon and Alloy Steels." Dr. Hoffman's paper was very instructive and entertaining, and was thoroughly enjoyed.

The discussion that followed the paper was fast and furious. Questions were put to Dr. Hoffman in rapid fire order, and he replied in like manner. The members derived a lot of good from these discussions.

Notwithstanding the fact that we moved this meeting up one evening to avoid a conflict with another technical meeting in the city, it was probably the best meeting we ever had in the Los Angeles Chapter. There were several new memberships placed in the hands of the secretary, and they should move Los Angeles Chapter far up towards the top of group two.

The nominating committee was appointed by our chairman, with instructions to report at the April meeting. *H. V. Ruth.*

NEW HAVEN CHAPTER

The February meeting of the New Haven Chapter started off as usual with a dinner at the Hotel Bishop as we always believe in having the inner man happy and contented before starting the meeting.

The speaker of the evening was Stanley P. Rockwell of the Stanley P. Rockwell Co., Hartford, Conn. who gave a very interesting talk on Dimensional Changes in Heat Treatment of Steel. The first part of the talk was illustrated with lantern slides while the second part was nicely told by moving pictures. The third part of the lecture was devoted to an acutal demonstration of a Rockwell Dilatometer. The discussion following the lecture was very good and from the expression of opinion of several present, the writer would say it was one of the most interesting evenings the New Haven Chapter has ever had. Again my hat is off to the chairman of the program committee for his excellent work.

The attendance prizes donated by W. Paul Eddy, Jr., of the Geometric Tool Co. and Russell S. Young of the O. K. Tool Co. were merchandise buying certificates for gent's furnishings but as the first prize was won by Miss Alice Halpin of the Seymour Mfg. Co., the chairman immediately had one of the certificates changed for the benefit of our fair representative from Seymour, Connecticut. You know the New Haven Chapter had the distinction of having the first lady member of the American Society for Steel Treating and although we have lost our original representative, we still have the fair sex represented in the Chapter. The other attendance prize was won by Mr. Zeigler of the William Schollhorn Co. Again it pays to be among those present.

The attendance was not as good as usual but what was lacked in numbers was made up in quality. Now that spring is approaching, the writer hopes the attendance will greatly increase. *Walter G. Aurand.*

NEW YORK CHAPTER

Despite a high wind and a drenching downpour, 200 members and guests of the New York Chapter attended the meeting held in the Auditorium of the Bell Telephone Laboratories, on February 14, 1928. The speaker of the evening was R. W. King, editor of the Bell Technical Journal; his subject was "Research and Development Activities of the Bell Telephone Laboratories."

After the address the group adjourned to the laboratory, of which F. F. Lucas is in charge. Here we were given an opportunity to see the complete

equipment in operation. The ultra-violet ray machine was on display and the dark room open for inspection. A corps of assistants were on hand to demonstrate apparatus and answer questions. We consider that the attendance was a great tribute to the high regard we all hold for Mr. Lucas. *E. E. Thum.*

The March meeting of the New York Chapter of the American Society for Steel Treating was a meeting extraordinary, being held Monday evening, March 12, in the Ball Room of the Hotel McAlpin.

The festivities started at 6:30 p. m. with a splendid chicken dinner. About 8:00 p. m., the dinner having been finished, the stage was arranged and the big show was on. Boxing bouts, vaudeville acts, and stunts by members of the chapter made the evening a gala affair.

As a diversion from the usual chapter meeting there were no speeches or technical papers, the meeting being devoted to a good time.

As usual the master of ceremonies was our able entertainer, E. P. Gaffney.

Many souvenirs presented by sustaining members were in evidence on the tables, and the large envelope which had been provided by the chapter was none too large in which to carry away the spoils.

PHILADELPHIA CHAPTER

The Philadelphia Chapter held a well attended meeting on February 24 at the Engineers' Club, the speakers of the evening being Prof. H. F. Moore of the University of Illinois, W. H. Eisenman, National Secretary, and A. W. F. Green, of the John Illingworth Steel Co.

Prof. Moore's paper was entitled "Fatigue Testing". His illustrations consisted of a reel of motion pictures and a number of lantern slides. The subjects treated dealt with the mechanism of fatigue failure, a short discussion of apparatus used for making fatigue tests, and the relative merits of different types of notches. The motion pictures were of great interest inasmuch as they had been made through a miscroscope and showed the actual course of rupture during a fatigue test. The lantern slides were of microscopic nature and photographs all illustrative of the trend of the paper.

Prof. Moore's personality coupled with a great appreciation of humor made the presentation of his paper so interesting that he held the attention of the entire audience for over an hour. The discussion served to show that he had made his subject very understandable.

Mr. Eisenman was received with great applause and in his inimitable way discussed some points of the Montreal meeting and also told some of the plans for the Western Metals Exposition to be held in Los Angeles during the early part of 1929.

The paper by A. W. F. Green, entitled "The Age of Tool Steel", was a practical discussion concerning the choice of tool steel from the consumer's standpoint. It was apparently well received.

The Philadelphia Chapter has been making some very splendid strides in its membership campaign and introduced eighteen new members at the meeting.

For those outside of our city, who may be nearby or here on or about

April 13 we extend a cordial invitation to visit with us the blast furnace of the Delaware Iron Co. and the A. H. Wirz Co. Inc., manufacturers of collapsible tubes, both located in Chester, Pa. *A. W. F. Green.*

PITTSBURGH CHAPTER

The February meeting of the Pittsburgh Chapter was held on the evening of the 2nd in the U. S. Bureau of Mines Building.

There were quite a few new faces at the dinner which was served in the cafeteria at 6:30. These dinners afford many members the pleasure of new acquaintances with mutual interests.

Motion pictures depicting oil operations in Poland, Greece and Egypt and including many historic and scenic views, were shown in the auditorium at 7:30.

At 8:00 o'clock, Chairman J. P. Gill called the meeting to order and, after the usual short business session, introduced the speaker of the evening, Dr. C. H. Herty, Jr., supervising metallurgist of the metallurgical section of the U. S. Bureau of Mines.

Dr. Herty spoke on the subject, "Open-Hearth Slags", and gave a most interesting history of the action and condition of the slag from the beginning to the end of a heat. With the aid of charts and photomicrographs, he pointed out the dangers that might be encountered and the corrective measures to be taken.

An unusually large turn out was very appreciative of Dr. Herty's talk, which invoked many questions during the general discussion which followed.

Harry A. Neeb Jr.

The Pittsburgh Chapter held its March meeting on the evening of the first at the U. S. Bureau of Mines. The dinner served in the cafeteria preceding the meeting was well attended by members and guests.

Beginning at 7:30 p. m. two Bureau of Mines motion pictures were shown in the auditorium; one showing "Explosives and Their Testing" and the other demonstrating "First Aid Methods in the Coal Mining Industry".

After the motion pictures, Chairman J. P. Gill called the meeting to order and conducted the Chapter's business session.

This being consummated, the Chairman introduced Mr. Finkl, Metallurgical Engineer of A. Finkl & Son, Chicago, makers of die blocks, as the speaker of the evening.

Mr. Finkl's subject was "Use and Manufacture of Alloy Steel Die Blocks," and he gave a most interesting outline of the development of the alloy steel die block and the difficulties encountered in its progress.

With the aid of several reels of motion pictures taken at the plant of A. Finkl & Son, he, then, showed the manufacture of die blocks from ingots and blooms to the finished product, including their heat treatment.

At the conclusion of the pictures, a general discussion was entered into which, from its length and varied character of questions asked, showed how closely and with what interest the members and guests had followed and appreciated Mr. Finkl's talk. *Harry A. Neeb, Jr.*

ROCHESTER CHAPTER

The regular meeting of the Rochester Chapter was held at the Hotel Osburn on February 13th. This was preceded by the usual informal dinner with forty-one members and guests present. At 7:30 p. m. the meeting was called to order and the speaker, T. Y. Olsen, was introduced. Mr. Olsen's subject was "Testing".

Mr. Olsen discussed the many phases of testing materials and described the tests as usually applied in commercial testing. He likewise described the various testing machines and their application in determining the various properties of metals in which engineers are vitally interested.

Numerous slides were shown of the many different kinds of testing machines in use. Following an interesting discussion, the speaker was given a rising vote of thanks.

H. J. LeClaire.

SYRACUSE CHAPTER

The regular monthly meeting of the Syracuse Chapter was held on January 10, with Thomas H. Wickenden, as the speaker of the evening. Mr. Wickenden, connected with the Development and Research Department of the International Nickel Co., is widely known in the automotive and alloy steel businesses for his papers and research on nickel steels.

The speaker read his paper "Automobile Design and Automotive Steels", illustrating many of his points with diagrams, tabulations and curves. He first justified the use of alloy steel for automotive parts and then described the design of some of these parts pointing out the pitfalls encountered by the designing engineer and some of the general precautions necessary to insure a decent safety factor in the designed parts.

"By keeping the physical properties of the steel in a part in proper coordination with the fatigue limit, safety and economy may be simultaneously affected. The automobile steering knuckle is a striking example of a vital automotive part subject to severe stresses of complicated nature. This part at one time designed with a 25 to 40 per cent factor of safety under static loading, is now built much stronger to take care of the additional but long ignored dynamic loading. In the same way the rest of the automobile running gear has been revamped and alloy steels have had a great hand in keeping down excessive weight in these parts."

Mr. Wickenden next took up the subject of gears. In his opinion alloy steel gears are surely a distinct advantage in automotive work. It developed that the main question was one of oil hardened versus case hardened gears. While the oil hardened gear possessed a higher tooth strength, it was subject to pitting and had a lower resistance to wear than the case hardened gear. The latter with its lower machining cost, counterbalanced with an increased cost of heat treatment owes its greater wear resistance, no doubt, to the high carbon content of the wearing surface, namely around 0.90 per cent carbon. The speaker knew of one popular car whose design embodied oil hardening gears. After ten thousand miles of service, these gears were badly pitted. A change to case hardened gears cured the trouble. In closing Mr. Wickenden recommended for automotive design in general , S. A. E. 3135 for forgings, 3215 for case hardened gears and 2345 for oil hardened gears.

The February meeting was held on Wednesday, February 8, in the Chamber of Commerce rooms. The speaker for the evening was E. L. Shaner, editor of Iron Trade Review, Cleveland. In presenting his subject, the speaker read his paper "The Status of the Steel Industry" and displayed and described in detail a curve of vital significance in steel production.

This curve being a composite of pig iron tonnage, coke production, steel ingot production, car loadings and a few others, was represented as a true index of the activity in the steel business. The curve shows an extreme low point in 1921 due to post war deflation. At this time Herbert Hoover, who even then had achieved some fame as an organizer and economist in Syracuse, first promulgated his Theory of Economic Recovery. Speculation, mismanagement, failure of supplies, poor deliveries, non-dependable statistics, waste of time and materials, and poor transportation facilities all were responsible, in some measure, for the depression in 1920-1921. Hoover stated that under these conditions American industry was scarcely 60 per cent efficient. He preached a doctrine of synchronizing efforts to relieve waste.

S. Peskowitz.

SPRINGFIELD CHAPTER

Sam Tour, the well known authority on salt baths, gave a talk on this subject at the monthly meeting held by the Springfield Chapter, February 20, 1928.

All angles connected with the use of salt baths were thoroughly discussed; uses, compositions, precautions to be observed and manner of heating.

Low melting points required in salt baths are obtained by a mixture of two or more salts and can be bought already fused or mixed by the user if so preferred. The fused salts are worth the higher price in that a certain loss takes place on fusing and if anything obvious is wrong with the salts it probably will be detected at this point. Watch out for impurities such as sulphur, as pitting and chemical attack of work and pots will occur from the use of an inferior, impure article. It is much cheaper in the end to buy the best technical grade.

The question of furnace design is a major factor in securing the best results from salt baths. Certainly a bath will not operate efficiently with burners playing directly on the bottom of the pot causing local overheating; increased sludge in the bottom, reduced conduction of heat and various other liabilities. Is the furnace correctly designed to obtain the maximum heating results from convection currents? Is it vented properly?

These are only a few of the many opportune questions Mr. Tour discussed during the evening; it would be impossible to enumerate here all the valuable facts he imparted to his audience throughout his talk.

After considerable discussion, the meeting closed with a plea by the chairman, Mr. Juppenlatz, for increased membership.

T. P. Jones.

ST. LOUIS CHAPTER

The 73rd regular monthly meeting of the St. Louis Chapter of the American Society for Steel Treating was held Thursday afternoon and

evening February 16, 1928, at the Administration Building of the Commonwealth Steel Co., Granite City, Ill. The meeting was preceded by a plant visitation and inspection trip through the courtesy of the Commonwealth Steel Co.

The members and guests, numbering some 200, which by the way is keeping up the record attendance of this chapter, enjoyed the wonderful experience of seeing large locomotive cylinder borers, millers and planers of all descriptions and also witnessed the machining of difficult castings weighing more than 40,000 pounds each. Some of the machines seen in operation have beds 100 feet long and 11 feet between housings. The Commonwealth Steel Foundry is the largest foundry of its kind in the world.

The speaker of the evening, W. H. Wills, metallurgist with the Atlas Crucible Steel Co., Dunkirk, N. Y., was introduced. Mr. Wills gave an excellent talk, illustrated with lantern slides, on the subject of the "Nature and Application of Principal Types of Tool Steel in use by the Industries of Today." An interesting discussion followed on both tool steel and castings. All in all, summing up the whole, the meeting was a wonderful success. The meeting was closed with a rising vote of thanks to the Commonwealth Steel Co. for allowing us to visit their plant and to the Atlas Crucible Steel Co. and Mr. Wills for the splendid talk before the Chapter.

Carl G. Werscheid.

The regular monthly meeting of the St. Louis Chapter was held Wednesday evening, March 14, 1928, at the American Annex Hotel. The meeting was preceded by the usual excellent dinner with an attendance that was indeed gratifying. After the dinner and a short business session the chairman, W. D. Thompson, introduced Dr. Edgar J. Swift, author of "How to Influence Men", and "Psychology and the Day's Work", who gave an illuminating talk on human nature which blended in very nicely with the psychology of men and metals and also blended with the talk which was given later by the principal speaker. Some of the points brought out of the gullibility of the human race brought forth many a chuckle from the audience.

The principal speaker of the evening, Jordan Korp, of the Leeds and Northrup Company, gave an excellent talk illustrated with lantern slides and drawings, the subject being "Tool Design and Heat Treatment in Relationship to Production." He dwelled principally on the hurry up methods in the hardening room of today, the first being the length of time in the heating of steels, second the rate of heating and the third the necessity of a known temperature of the quench. Mr. Korp contended that there is more steel and fine tools ruined by improper heating and quenching than there is in any other operation. The meeting was adjourned at 11:15 p. m. with a rising vote of thanks to Dr. Edgar J. Swift for his excellent talk and to Mr. Jordan Korp and his Company for their courtesy of appearing before our chapter. There is no doubt that all who missed this meeting missed a treat, but if any more members and guests had been present we would have had to hire another hall. Three attendance prizes were awarded; the first prize was won by Leo Schildknecht, but he will have no use for it until Thanksgiving; the second prize was won by C. W. Warner and the third prize was won by Hugh Waltrip. *Carl G. Werscheid.*

TRI-CITY CHAPTER

The regular monthly meeting of the Tri-City Chapter of the American Society for Steel Treating, was held at the Peoples Power Company's Auditorium on Thursday evening, January 26, 1928.

After a short business session the Chairman, E. H. Sohner, introduced the speaker of the evening, Robert G. Guthrie, metallurgist for the Peoples Gas, Light and Coke Company, of Chicago, Illinois. Mr. Guthrie's talk was on the subject of "Carburizing with City Gas". The theory of the process along with operating details were brought out in the talk. Likewise the great future possibilities of the process were brought out. This conclusion was arrived at because of the low costs of the process as compared to the "pack" method of carburizing. The quality of the product is increased, as is the uniformity of the case produced.

Considerable discussion followed the talk—Mr. Guthrie answering all questions very satisfactorily.

The meeting adjourned with a rising vote of thanks to the speaker.

George A. Uhlmeyer.

Thirty-five members of the Tri-City Chapter on February 22, 1928, attended the dinner and talk by Dr. V. O. Homerberg of the Massachusetts Institute of Technology. Dr. Homerberg explained the development of nitrided steels in Germany and more recently in the United States. He also explained the theory of the new process, along with the equipment necessary to treat the steel. He pointed out that the physical properties of nitrided steel were much better than of the ordinary carburized steel, principally in the fact that it is intensely hard and for that reason resists wear to a very remarkable degree.

Although this process is more or less in the development stage, anyone hearing the talk would very readily appreciate the enormous possibilities of the new process. It is possible that in the course of time it may almost entirely supplant the process of carburizing as we know it today.

George A. Uhlmeyer.

WASHINGTON-BALTIMORE CHAPTER

R. S. Archer spoke on "Aluminum Alloys" at the January meeting, which was held in the Interior Department Auditorium on Wednesday, January 18. He gave a very interesting account of the discovery and development of aluminum, emphasizing the fact that aluminum is a comparative newcomer among the metals, its entire commercial and industrial history being a matter of only one generation. Mr. Archer then compared the properties of the various copper, zinc, and silicon alloys of aluminum which have been developed to meet the demands for castings of high strength and toughness. In these respects heat treated duralumin castings are better than the aluminum-zinc-iron, or the aluminum-silicon alloys. Wrought and heat treated duralumin (copper 4 per cent; magnesium ½ per cent; manganese ½ per cent has a tensile strength of 55,000 to 65,000 pounds per square inch and a reduction of area of 18 per cent, but the ingots are difficult to work. Alloys 25S (copper 3.9 to 5 per cent; manganese 0.5 to 1.1 per cent; silicon 0.5 to 1.1 per cent) and 51S

(magnesium 0.45 to 0.8 per cent; silicon 0.6 to 1.2 per cent) have similar properties but are easier to work.

At present the greatest development is taking place in the processes of manufacture of the aluminum alloys along the lines of automatically controlled heat treatment and the technique of handling molten metal in large quantities. Complicated castings are being made without warping and cracking in sizes up to 9,000 pounds.

Mr. Archer gave a very striking lecture table demonstration of the great superiority which duralumin, because of its lightness, has over steel in regard to the stiffness of structures built from these metals. Stiffness depends on the section modulus and the elastic modulus of the material. The elastic modulus of steel is 30,000,000 and that of aluminum is 10,000,000, so that in regard to elastic modulus, steel has a 3 to 1 advantage over duralumin. However, duralumin is approximately one-third as heavy as steel so that for the same weight a duralumin member would have a cross-section three times as thick as steel. Since the stiffness of a section is proportional to the cube of the thickness, this gives an equal weight duralumin section an advantage of 27 to 1 in stiffness, as regards section modulus. If duralumin were exactly one-third as heavy as steel the stiffness of an equal weight section of duralumin would be nine times that of steel but as duralumin is somewhat more than one-third as heavy as steel the ratio is 7 to 1. It is this fact which makes duralumin indispensable in airship construction. *S. Epstein.*

On February 17, 1928, the Washington-Baltimore Chapter held a very interesting colloquia on the hot and cold working of steel, ably led by J. D. Armour of the Union Drawn Steel Co., and J. E. Malloy of the American Tube and Stamping Co.

Mr. Armour first briefly reviewed the rapid development of the cold finishing bar industry stating that it is today the largest consumer of merchant bars, which has been due particularly to the demand of the automotive, typewriter, cash register, and other industries which use automatic machinery for the rapid duplication of parts for which cold drawn steel is particularly suitable because of its easy machinability.

Cold drawn steel is now classified in a few well known groups descriptive of type and process in particular "cold rolled", "cold drawn", "turned and polished", "special finish" (including ground finish and piston rod finish), "shafting", "cold upsetting stock" and "special shapes". The "cold rolled" process has largely been replaced by the "cold drawn" process because of the better quality and more uniform product obtained.

Details of the processes of production and resultant properties were given, including micrographs of good and poor machining structures.

The numerous types and kinds of "special shapes" illustrated and described were of particular interest and emphasized the economies to be gained in reduced machining costs and materials by their use.

Mr. Malloy discussed the hot and cold rolling of steel, particularly strip steel, the greatest production of which is made from S. A. E. 1020 type steel and widely used for drawn or stamped products. A considerable quantity, how-

ever, of other types are used, particularly S. A. E. 1055, for motorcycle and similar chain and S. A. E. 1090 for springs, knives, ice skate runners and similar products.

A brief review of the open-hearth and pouring practice was given in which sources of difficulty in subsequent rolling operations were brought out, particularly, the necessity for correct temperature of pouring and the prevention of splashing in the molds.

A full and broad discussion followed the talks. *J. R. Freeman.*

NOTES FROM THE U. S. BUREAU OF MINES

MAKING CAST IRON IN THE ELECTRIC FURNACE

ALTHOUGH the cupola is the cheapest melting device for the production of molten iron under normal market conditions for pig iron, coke and clean cast iron scrap, there are conditions under which expense of melting is not the major factor, so that certain other advantages possessed by the electric furnace sometimes make it more desirable, says the United States Bureau of Mines, Department of Commerce. A comprehensive investigation of the making of electric-furnace cast iron has been completed by the bureau at its Northwest Experiment Station, Seattle, Washington, in co-operation with the College of Mines of the University of Washington. The investigation involved a year's successful operation of a jobbing foundry making miscellaneous gray iron castings from steel scrap.

Under the special conditions that make the electric furnace advantageous, this type of furnace need not necessarily displace the cupola, but can be used in conjunction with it. The ability of the electric furnace, and not of the cupola, to refine and to superheat iron and the superiority in many ways of electric furnace iron to cupola iron make the electric furnace advantageous under special conditions. In addition, the possibility of producing electric furnace cast iron from cheap grades of ferrous scrap has brought the electric furnace into prominence.

Electric furnace cast iron is stronger, tougher, and more dense than cupola iron, and a higher recovery of metal in casting can be obtained as a result of the higher pouring temperature, state C. E. Williams and C. E. Sims, in Technical Paper 418, just issued by the Bureau of Mines. Cast iron scrap of high sulphur content can be converted into high grade cast iron, low in sulphur, either by melting directly in the electric furnace or by refining molten metal from the cupola. Large additions of steel scrap may be used if desirable, or steel scrap can be used entirely and synthetic cast iron made. Some of the advantages of the production of synthetic cast iron are outlined below.

One electric furnace can be used to produce both iron and steel and can thereby be kept in operation during periods when it might otherwise be idle. By operating an electric furnace continuously labor is kept usefully employed, the heat of the furnace is conserved, life of the refractories is extended, overhead charges are reduced, and a high load factor on the power lines is maintained. Therefore, even under conditions where production of synthetic iron would not of itself be economical, it might be profitable in conjunction with

the making of steel, because of the possibility of reducing the cost of producing steel.

A large variety of steel and iron scrap can be used to make the same product, and many different products can be made from the same materials. As a rule, scrap is purchased locally, and the foundryman can buy and use what is at hand without shopping around for special materials. The production of synthetic iron in a steel foundry simplifies the purchase of steel melting scrap. For instance, the making of acid steel requires selected scrap for which a higher price must be paid than for general scrap; but if, in addition to steel, synthetic iron is made, miscellaneous steel scrap may be purchased at a minimum price and the foundryman can do his own sorting, using the best scrap for acid steel.

Synthetic iron may be tested and adjusted for composition and temperature before it is poured, thus assuring castings of the desired composition. Moreover, if the pouring crew is not ready, the metal can be kept hot as long as necessary, whereas metal must be taken from the cupola when enough has been melted to pour.

In the electric furnace a superior iron, having about twice the strength of ordinary cupola iron, can be made. Transverse strengths of 5000 to 6000 pounds on standard bars of synthetic gray iron have been repeatedly obtained, and tensile strengths above 40,000 pounds per square inch are common. One of the outstanding characteristics of electric furnace gray iron is its resistance to impact or shock. These advantages in strength and toughness are due largely to the physical structure of the iron, which is fine-grained and dense. The graphite exists in such small flakes that a piece of synthetic iron of the same graphitic carbon content as a piece of cupola iron will appear to contain less graphite. Although it looks whiter and harder than cupola iron, synthetic iron is soft and easily machined. A coarse-grained synthetic iron can be obtained only when the carbon and the silicon contents are exceptionally high. Ordinary synthetic iron is at least equivalent in strength to the so-called high-test irons and semi-steels of the cupola.

Virtually any kind of ferrous scrap can be used in the electric furnace, thus providing a means for industrial plants to utilize the scrap they produce instead of shipping it away at an economic loss. Besides steel scrap, which may be carburized to gray iron, gray iron borings and light scrap may be used profitably.

The production of synthetic cast iron in the electric furnace is advantageous in such places as large nonferrous smelters and mills, where pig iron is expensive and ferrous scrap is usually available. Many ore concentration plants consume a large tonnage of steel and iron balls and ball mill liners for fine grinding, and satisfactory white cast iron for these purposes could be made economically at the plant.

A tough and hard white iron, such as may be produced in the electric furnace from steel scrap, will find useful application where resistance to shock and abrasion are required

The detailed results of this investigation are given in Bureau of Mines Technical Paper 418, "Electric Furnace Cast Iron."

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